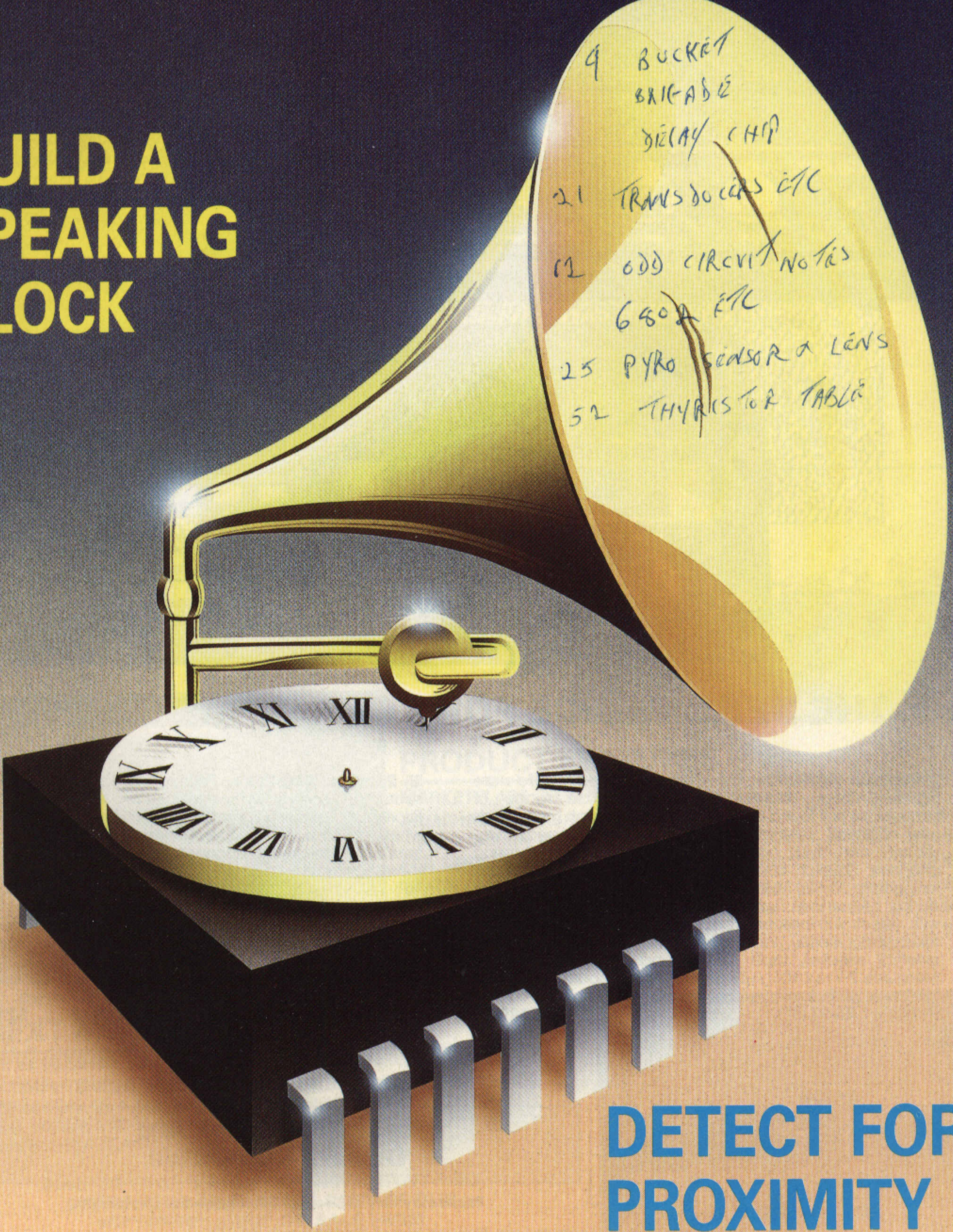
PRACTICAL

ELECTRONICS

AUGUST 1988 · £1.25

SCIENCE & TECHNOLOGY

BUILD A SPEAKING CLOCK



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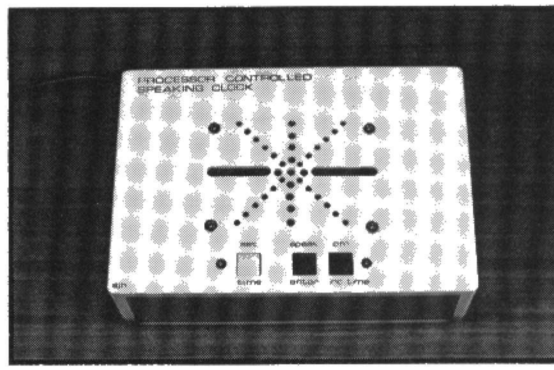
DETECT FOR PROXIMITY

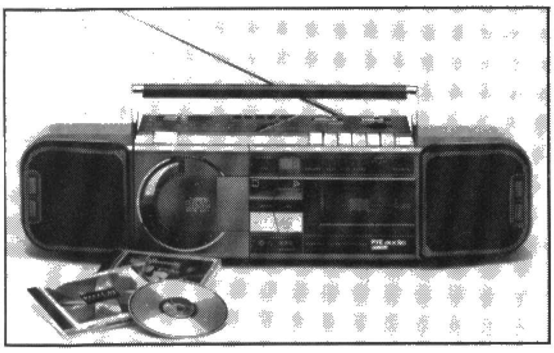
THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS AND COMPUTER ENTHUSIASTS

PRACTICAL ELECTRONICS

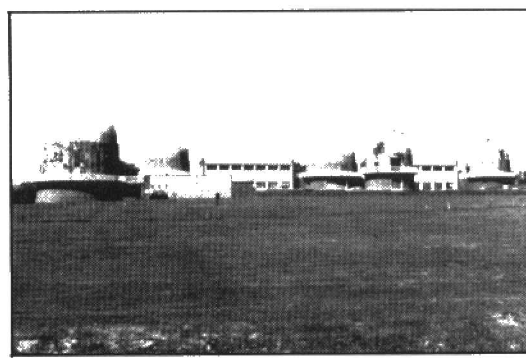
PE VOL 24 NO 8 AUGUST 1988

CONSTRUCTIONAL PROJECTS

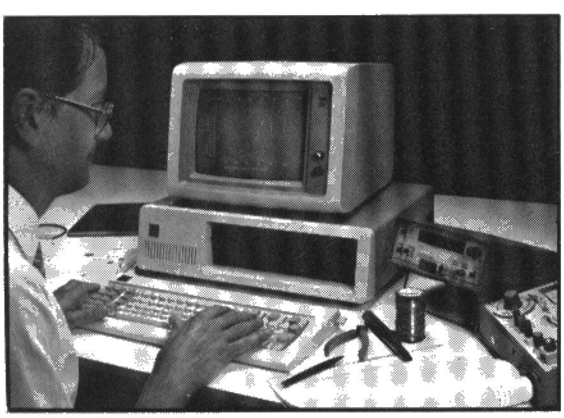




SPECIAL FEATURES



REGULAR FEATURES



PRODUCT FEATURES

NEXT MONTH . . .

WE'VE BEEN PRESSURED TO TAKE A STAR-SPANGLED LOOK AT –

A COMPUTERISED BAROMETER • ASTRONOMICAL ELECTRONICS • MUXXING-OUT THE BEEB • MICROPROCESSOR DEVELOPMENT • CD ROM • AND IT'S BACK TO THE CHALK-TALK FOR THE START OF ANOTHER CLASSIC GCSE TUTORIAL SERIES •

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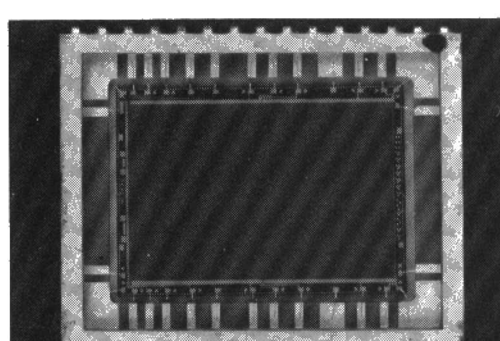
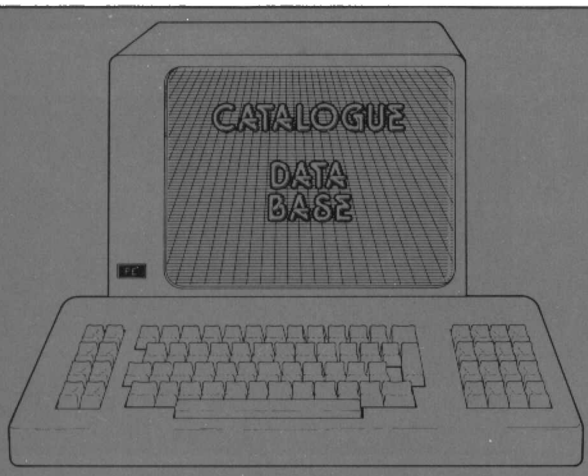




We have recently received the following catalogues and literature:

STEBUS USERS. In response to many requests the STE manufacturers and users group has produced the STE Awareness Brochure, which is now **available free of charge to intending users of the STEbus.** The brochure answers many questions asked by first time users of the STEbus, detailing its structure, protocols and characteristics. **STE Manufacturers and Users Group,** PO Box 149, Reading, Berks, RG3 3HB. 07357 4976.

Thurlby Electronics have a new eight page full colour shortform catalogue of their range of **test and measurement equipment. Thurlby Electronics,** New Road, St Ives, Huntingdon, Cambs, PE17 4BG. 0480 63570.

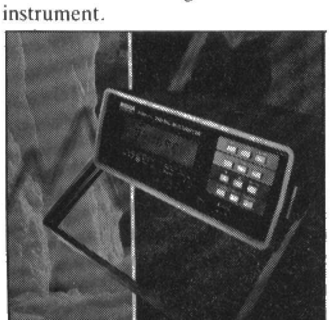
Thame Components have sent the Harris Analog Pocket Application Guide No 5. Over 100 pages of **audio opamp specifications and applications notes** relating to Harris Semiconductors make this a worthwhile addition to any serious designer's bookshelf. **Thame Components Ltd,** Thame Park Road, Thame, Oxon, OX9 3XD. 0844 214561.

Anville Instruments' multipage brochure outlines their **range of standard and custom-built thermocouple,** platinum resistance thermometer and thermistor temperature sensors. **Anville Instruments,** Watchmoor Trade Centre, Watchmoor Road, Camberley, Surrey, GU15 3AJ. 0276 684613.

West Hyde Developments have just celebrated their 25th Anniversary and we are sure that they would be delighted to send information about their **range of boxes and other enclosures** to anyone with a serious interest. West Hyde were one of PE's founding advertisers and as part of their celebrations they had on display a copy of PE Volume 1 Issue 1. (We at PE shall also be celebrating our 25th anniversary soon — doesn't time fly when you're popular?). **West Hyde Developments Ltd** are at 9–10 Park Street Industrial Estate, Aylesbury, Bucks, HP20 1ET. 0296 20441.

Schlumbering Quietly

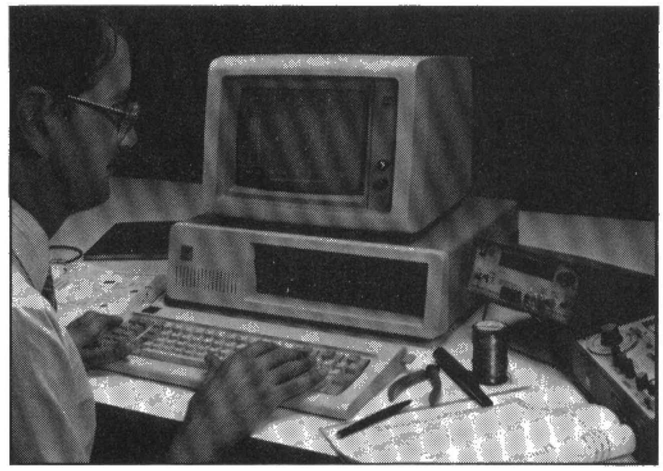
A full-colour eight-page brochure from Schlumberger describes their new 7150plus digital multimeter, detailing the many novel features of this 3½- to 6½-digit versatile instrument.



Features include a smart automatic digital filter which reduces noise to ±1 count, measurement of dc voltage and current, true rms voltage and current, resistance and temperature. A GPIB interface is also included, as are designed-in reliability, fast and simple remote or front-panel calibration, and exceptional ease of use. The brochure outlines the manufacturing philosophy and the stringent factory testing which enable Schlumberger to offer a two-year warranty on the instrument with a promise of outstanding life expectancy.

Contact: Bernard Parkes, Schlumberger Instruments, Victoria Road, Farnborough, Hants, GU14 7PW. Tel: 0252 54433.

WHAT'S NEW



HF Analyser

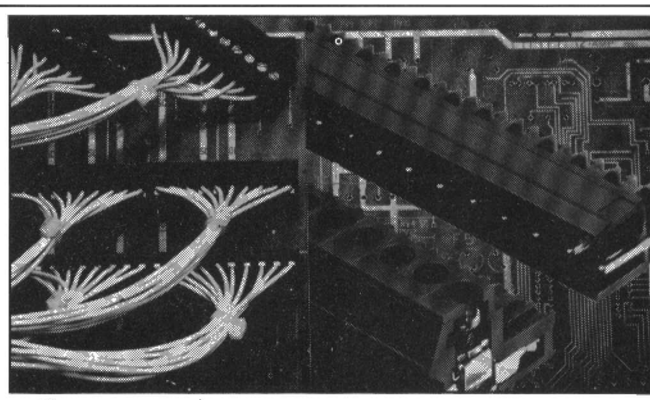
Number One Systems' popular PC circuit analysis package, Analyser II, has been the subject of a major revision to include analysis of microwave striplines and transmission lines. An extremely rare feature in low cost design tools, analysis of these high frequency components will make a large contribution to taking away the difficulty and 'black art' nature of hf circuit design.

This addition will offer design engineers at rf and higher frequencies the facility of rapid evaluation of designs that include these elements for gain, phase, input and output impedance, and group delay. The resulting ease of seeing the effects of design changes and tolerances means that designing hf networks is no longer a chore.

Other benefits to users are the avoidance of expensive test and measuring equipment, and the need for continued breadboarding during circuit development. These are particularly awkward issues in rf design work. Results of the analysis are presented in tabular or graphic form so the user can spot and measure response peaks and notches, phase reversals, and impedance changes where matching is important.

Analyser is supported by free updates for six months, and a telephone query hotline. Its operating system is for PC-DOS and MS-DOS, needs a memory of 192K minimum, and a disk size of 5¼inch. The price is £195.00 plus VAT.

Contact: Number One Systems Ltd. Harding Way, Somersham Road, St Ives, Huntingdon, Cambs PE17 4WR Tel: 0480 61778.



Klippons

A new modular connector system for pcbs has been announced by Klippon.

The BLA/SLA range is available in a single row format from 2 to 24 poles and in a double row format with up to 48 poles. In addition to its modular facility, which permits block building to suit individual customer requirements, the system features ease of termination as well as assembly and is designed to be vibration-proof. Manufactured in pbtp for high reliability and stable performance, BLS/SLA has an operational temperature range of 120°C and a 8A current rating.

Contact: Klippon Electricals, Power Station Road, Sheerness, Kent ME12 3AB. Tel: 0795 580999

Hot Charts

Electronic Temperature Instruments are pleased to announce to PE readers the addition of the Rustrak chart recorders to the range of temperature measurement instrumentation.

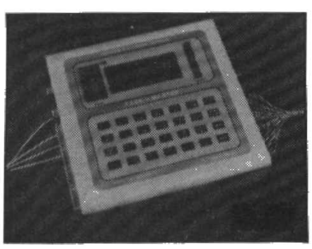
Rushtrak strip chart recorders are available to measure both temperature and humidity. The compact size and flexibility of the recorders make them ideal for continuous monitoring of computer rooms as well as component storage areas.

The temperature recorders are available utilising Pt100 or thermocouple probes. E.T.I. manufacture a wide range of temperature sensors, providing almost limitless range capability. Multi-channel recorders can be used for independent recording of up to four channels, particularly useful as a number of rooms or buildings can be monitored at one central point.

The humidity chart recorder is designed to monitor both temperature and relative humidity of air. The recorder samples the humidity sensor every eight seconds and prints a dot on the chart. Four seconds later, the recorder switches to the temperature channel and its sensor. The series of dots make continuous lines that are easy to read.

The prices start at £199.00 for the basic temperature recorder. Quantity discounts are available.

Contact: Electronic Temperature Instruments Ltd, PO Box 81, Worthing, W. Sussex, BN13 3PW. Tel: 0903 202151.



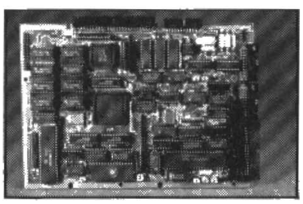
Topform

User-friendliness is one of the keywords used by Topform Electronic Services in describing their new Task-Master 901.

Representing a new concept in low cost programmable controllers the Task-Master offers an innovative low cost alternative to in-house custom built test equipment and plcs. Using basic programming the unit can be expanded in a 'family' concept manner through various add-ons. The current family members include a-d, d-a, RS232, and an 8-bit bidirectional version. A multitasking facility enables up to ten routines to be performed in parallel with the main program. Integral program storage is via an eprom and enables dedicated computer use.

The Task-Master 901 is available on a free ten-day trial offer and is priced at £255 with add-ons starting from £150.

Contact: Topform Electronic Services, Unit 60, Buddle Road, Clay Flatts Industrial Estate, Workington, Cumbria, CA14 3YD. Tel: 0900 67436.



All Aboard

The SB180FX single-board computer announced by JB Designs contains all that is needed on an OEM and is based around the high-integration HD64180 Z80-compatible microprocessor, and has a complete set of peripheral interfaces.

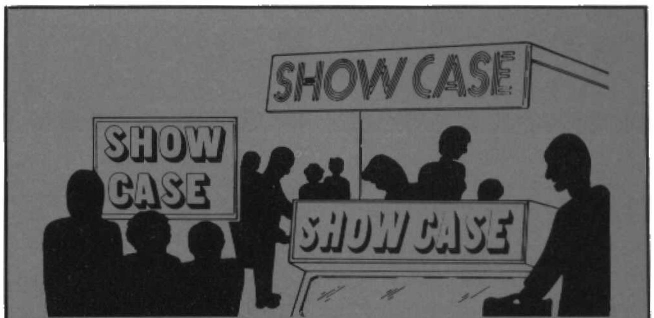
Both floppy and optional hard disc interfaces are built-in and facilities are provided to drive a Centronics printer, a modem and an operator terminal. In addition there are 24 lines of uncommitted parallel IO.

The board is available without software, or with a full suite of operating system, monitor, assembler, linker, debugger and a wide range of utility programs. The extra facilities of the HD64180 cpu allow it to address a full 512K bytes of dram which can be fitted to the board. Most of this is easily configured as a ram-disc.

The card can be used alone, or combined with the GT180 graphics expansion card, which provides high resolution graphics using the Hitachi HD64384 ACRTC graphics processor.

The one-off price of the board, without software, is £259.

Contact: J.B. Designs & Technology Ltd, 15 Market Place, Cirencester, Glos. GL7 2PB, Tel: 0285 68122.



COUNTDOWN

If you are organising any event to do with electronics, big or small, drop us a line – we shall be glad to include it here.

Please note: Some events listed here may be trade or restricted category only. Also, we cannot guarantee information accuracy, so check details with the organisers before setting out.

Regular courses for R.A.E., and also for Morse. Grafton Radio Society, Elizabeth Garrett Anderson School, Riseing Hill Street, London N1.

Regular weekly courses for Radio Amateurs Exam (C8G 765). Tuesday 7.30 to 9.30. Hendon College, Corner Mead, Grahame Park, Colindale, London NW8 5RA. Tel: 01-200 8300.

Jul 1-2. Minster School Science Fair, displaying the most up to date products in school science equipment, books, software etc. Local and national industries will also demonstrate the relevance of science education in their own fields. M. Bossard, The Minster School, Nottingham Road, Southwell, Notts NG25 0HG. Southwell 814000. *PE like to publicise events of this nature.*

Sep 6-8. Coil winding. Wembley Conference Centre. 0799 26699.

Sep 8-12. Sim-Hifi Ives. International video and consumer electronics show. Milan. 02-4815541.

Sep 27-30. DES. Design Engineering Show. National Exhibition Centre. Birmingham.

Oct 11-13. British Laboratory Week. Grand Hall, Olympia. 0799 26699.

Oct 18-20. Internepoon. Electronic Packaging Show. Metropole Convention Centre, Brighton.

Nov 1-3. Custom Electronics & Design Techniques Show. Heathrow Penta. 0799 26699.

Nov 29-Dec 1. DMC-PC. Drives, motors, programmable controllers etc. National Exhibition Centre, Birmingham. 0799 26699.

Syncing Clock

The GPS-DC synchronised clock has been launched into the UK by Measurement Limited as a low cost time and frequency addition to its Global Positioning System product range.

A truly global instrument aimed at a wide range of applications, the clock is designed to provide precise time within ± 200 nanoseconds. As well as a sharp visual display, the clock offers IRIG-B time code, RS 232 interface, 1/5/10 MHz squarewaves and a 1Hz reference pulse as the ultra-precise time mark. This capability makes it a cost-effective option for communications, standards laboratories and geophysical applications, as well as the scientific community.

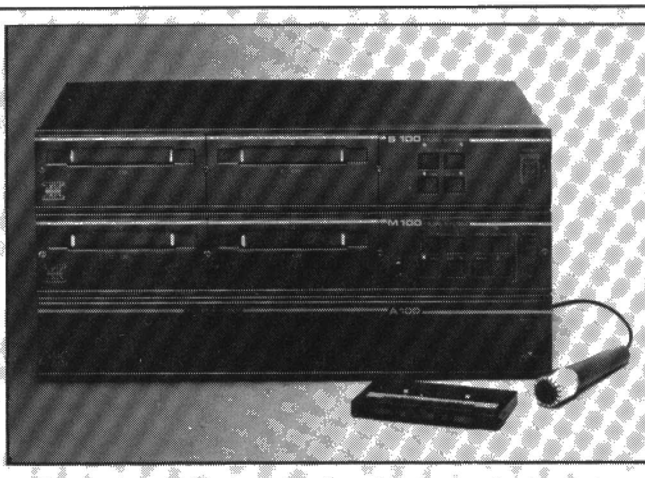
Its simple operating routines mean the user has only to select the best antenna site and enter his position (±1°) before the GPS-DC becomes fully automatic — including the acquisition of the best satellites. The instrument's three most used functions — time, status and position — have been reduced to single button operation, while all other features are addressed via a 16-key pad on the front display.

Contact: Measurement Limited, Berrington Road, Leamington Spa, Warwickshire, CV31 1NB. Tel: 0926 35411.

Gemini Spotted

Gemini have introduced a new microprocessor controlled music system which provides a cost effective solution where background music and spot announcement facilities are required for business, leisure and workplace environments.

The 100 Series system features attractive styling and state of the art electronic circuitry to make it not only highly functional and compact, but easy to install and operate. It is ideal for pubs, clubs, restaurants, hotels, retail outlets, leisure centres and factory workplaces. And its modularity means it can be configured for large and small places and spaces as well as integrating with users' existing equipment. One module can be incorporated to enhance a current system and others added later as required.



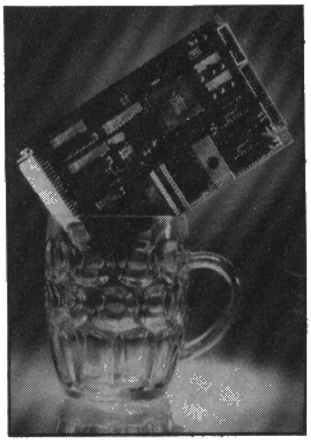
Three main modules comprise the system: the M100 master unit, the A100 amplifier and the S100 optional slave unit.

The M100 has twin autoreverse cassette decks and the latest touch switch controls and led indicators for tape eject/advance, treble, bass and volume adjustments. For ease of access, the mic input connector is located on the rear panel and a control button on the microphone allows for spot announcements with simultaneous music fade out. An auxiliary connection point on the rear panel allows users to operate their own radio or compact disk through the system.

When additional playing time is required, users simply connect the S100 twin autoreverse cassette unit to their M100. Up to eight slave units can be plugged in to give a continuous and unattended playing sequence of 18 cassettes.

Output from the A100 amplifier is 100 watts plus per channel of professional quality sound in stereo or mono over multi-speaker arrangements. There are additional power options of 30W/50W/100W, 8 ohm impedance (stereo/mono) or 100 volt line output (mono only).

Contact: Gemini Systems Ltd, Unit 5, Watchmoor Road, Camberley, Surrey, GU15 3AQ. Tel: 0276 683744.



Pinting The Way

DSP Design are the first company to offer an ste bus processor board based on the V25, the latest high integration 8086 code-compatible microcontroller from NEC. The PC-compatible processor means that popular MS-DOS software development tools available for the IBM PC can be used to generate target code fo the SV25 board.

The all cmos design makes it ideal where low power consumption, high noise immunity and extended temperature range are important factors in maximising system reliability. Running at 8MHz, the SV25 packs the greatest range of functions yet seen on a single ste bus Eurocard.

Three bytewide memory sockets each support eprom or ram devices from 8K to 128K bytes. Another socket is provided to accept serial eeprom devices up to 2K bytes to hold security or configuration information.

Contact: DSP Design, 100 St Pancras Way, London NW1 9ES. Tel: 01-482 1773.

Intelligent Architecture

Intel are consolidating the future of their 32-bit microprocessor architecture. In a thick pile of information recently released they have announced 16 new vlsi products and development tools designed specifically for embedded control applications. The products include the new 80960 32-bit microprocessor and its first three derivative processors, plus a customised 386 microprocessor. Flash memories and a new non-volatile memory technology are also being introduced.

Embedded control processors, controllers and memories are semiconductors designed to be programmed to manage specific tasks. They are then 'embedded' into products to provide them with intelligence and functionality. Typical applications range from consumer electronics (eg vcrs, cd players, microwave ovens) to office equipment such as copiers, laser printers and modems. Transportation, avionics, industrial automation, telecommunications and automotive products represent other suitable applications.

The 80960 architecture uses risc (reduced instruction set computer) design techniques to deliver a high performance architecture that can be easily modified or proliferated into market-specific processors. (Sir Clive Sinclair spoke of risc architecture in the feature published in PE Jun 88). Intel will use this 'core architecture' as a basis for 32-bit embedded processors well into the next decade.

Busby's Public Challenge

Oftel report that the first step has been taken to introduce competition in the provision of payphone services. Currently British Telecom have the monopoly in public call boxes, but Mercury Communications are to be allowed to provide a similar service.

The new call boxes will connect directly to Mercury's digital network and will accept coins and credit cards. The possibility of other companies operating public call boxes is being considered.

Let's hope that competition will drastically reduce the number of out-of-order boxes currently experienced. Oftel reports that in a recent independent survey, of 7000 call boxes visited nationwide 24% were out of order. My wife's recent independent survey of seven call boxes revealed 100% failure at our local railway station — she had to walk three miles home as she'd missed the bus and couldn't phone me!

Oftel are at Atlantic House, Holborn Viaduct, London EC1N 2HQ. Tel: 01-822 1644 and 01-353 4020.

CHIP COUNT

New component details received:

74F30XXX range. The high performance fast buffers and transceivers in this range have been specifically designed to handle low impedance environments of pcb backplanes and signal busses. They can drive lines with characteristic impedances as low as 30 ohms. Other features include — incident-wave 30 ohm transmission line switching, high output currents (+160mA and −67mA), 'flow-through' signal design, multiple centre-package supply pins, low Vcc shut-off circuit, 'light-load' ±20μA npn inputs.

The devices now available are —

N74F3037. Quad 2-input nand totem-pole buffer.

N74F3038. Quad 2-input nand open collector buffer.

N74F3040. Dual 4-input nand totem-pole buffer.

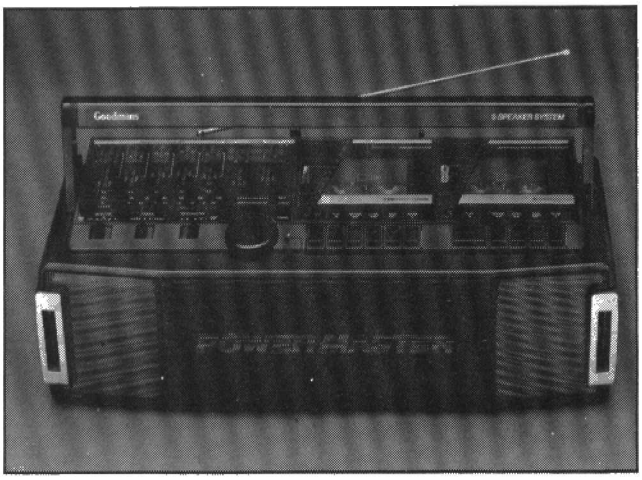
N74F30240. Octal inverting open collector buffer.

N74F30244. Octal non-inverting open collector buffer.

N74F30245. Octal non-inverting transceiver.

N74F30640. Octal inverting transceiver.

These devices are manufactured by Philips Components Ltd, Mullard House, Torrington Place, London WC1E 7HD. 01-580-6633. (Philips Components is the new name adopted by Mullard.)



Quadro Power

Goodmans have expanded their range of portables with the introduction of the SW840 Powermaster and Quadro 901 portable tv/radio.

The SW840 is the latest addition to Goodmans range of high performance, Powermaster radio/cassettes. Featuring a double cassette, with 5-band graphic equaliser, high speed dubbing and continuous play, the SW840 has a five speaker system for superior sound. Two 4in bass units and two piezo tweeters, combine with a further bass unit with separate amplifier for extra boost all combine to provide a powerful portable at a retail price of around £90.00.

The Quadro 901 joins a comprehensive range of radio, black and white tv and cassette units. Retailing around £79.90, it features a 5in black and white tv with mw/vhf radio. The 3-way power operation of the 901 provides versatile usage in the home, car, boat, caravan etc, and comes with its own shelf stand.

Contact: Sharon South/Celia Lynch, Goodmans, 2 Marples Way, Kingscroft Centre, Havant, Hampshire, PO9 1JS. Tel: 0705 486344.

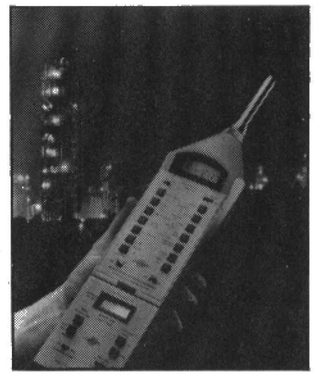
Noise Noser

Bruel & Kjaer have highlighted an advanced new instrument combination for simple determination of the frequency content of noise.

The combination provides a solution which is both powerful and easy to use for wide-ranging applications such as circulation of noise rating values, detection of tonal sources in boundary noise investigations, determination of noise reduction strategies, and specification of hearing protectors.

The measurement system is based on the handheld 2231 Modular Precision Sound Meter, which is fitted with a frequency analysis module controlling a 1/1-1/3 octave filter set. The module maintains use of the 2231 as a normal integrating sound meter, and to the high intrinsic performance of the instrument adds the computing power to yield accurate frequency analyses.

Hardcopy of results in an easily-understood graphical or digital format is obtained by using BK's 2318 portable



documentation printer, or an alternative compatible printer via the serial interface.

According to the type of noise under assessment, various parameters such as sound incidence, full scale deflection and time weightings can be set on the sound level meter. To increase the versatility of the measurement system numerous special functions, for example a fixed integration time per channel, or a particular printout mode or format, can be selected.

Contact: Bruel & Kjaer (UK) Ltd, 92 Uxbridge Road, Harrow HA3 6BZ. Tel: 01-954 2366.

Mini Radio Times?

Sony has introduced a tiny new receiver with most of the facilities of the paperback-sized ICF 7600D in an audio cassette sized package.

The new model is the ICF-SW1S, selling at around £250, is available in a convenient briefcase styled carrycase to cater for robust treatment.

In the case you'll find the receiver itself, an active antenna, multivoltage ac adapter for use from mains power anywhere in the world, and high quality stereo headphones. Sony also throws in a copy of its latest "Wave Handbook" to identify the signals available.

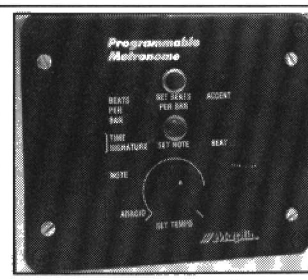
Capable of receiving fm stereo, mw, lw and sw, the radio is the ideal business or holiday travel companion. Sony has a proud tradition in radio technology, introducing their first transistor radio in 1957.

The ICF-SW1S has pll synthesised tuning and a memory which enables the user to store 10 favourite stations from across the bands. Travellers will also enjoy the fact that it doubles as an alarm clock.

"We have thought through every stage of this receiver and tried to come up with a package which offers great benefits with no need to buy things like ac adapters, headphones, or antenna as extras. With the SW1S everything comes in one convenient package," says Yoshi Nagayawa Sony Radio Marketing Manager.

"It's a good job we changed the name to Sony all these years ago, I don't think that the old name of Tokyo Tsuchin Kogtyo Kabushiki Kaisha would have fitted on a receiver so small," he joked.

Contact: Andrea Coppen, Sony (UK) Limited, Sony House, South Street, Staines, Middlesex, TW18 4PF. Tel: 0784 67371/67385.



Beating Maplin

The all new Maplin programmable electronic metronome is designed to be an essential item of equipment for musicians of all persuasions and capabilities from hi-brow to hi-beat.

Its features include audio and visual beat and accent indication, variable tempo from slow (adagio) to fast (presto), programmable time signature on 7-segment displays.

Despite its robust construction, the unit is light weight, compact and easily transportable. It is housed in a small plastic box incorporating a 9V battery.

The module kit, reference LM49D, can be assembled in a short time by any electrical, electronic or audio enthusiast, and costs just £26.96 including vat. It is available from any Maplin shop.

Hi-D ccd cam

Mitsubishi Electric Corporation of Japan has developed a high-definition charge-coupled device (ccd) camera suitable for monitoring uses.

It is the industry's first one-million pixel ccd camera with a built-in electronic shutter and the ccd used in it was jointly developed by Mitsubishi Texas Instruments.

The HT-1000S employs a superhigh-density ccd with one million pixels as the image sensor and has a high-speed electronic shutter with a speed of up to 1/2,600 second to capture a subject travelling or rotating at high speed as a clear black-and-white still image.

The image section is 1,024 pixels (horizontal) by 512 pixels (vertical), as the horizontal resolution is more than 850 lines for a clean image. Large-scale integration chips are used for the ccd peripheral circuits to ensure a long life and high reliability. The camera, 70mm wide, 70mm high and 210mm deep, weighs about 950 grams.

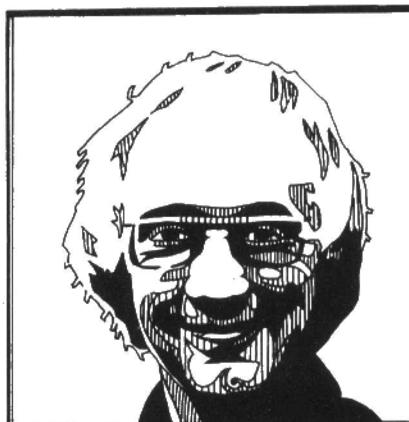
The development of the HT-1000S by Mitsubishi Electric expands the applications of ccd cameras to new areas. The company expects the HT-1000S to be used in industrial, monitoring and research areas for character and shape recognition, flaw detection and measurement.

CRYSTAL GAZING'S COLOURFUL FUTURE

By Barry Fox
Winner of the 1987 UK Technology Press Award

THE SCREEN THAT FELL FLAT

Take your pixels – before somebody else does. The deepest frustration belongs to those who toil and sweat and can't get to market.



In 1953 Lord (J. Arthur) Rank, of the Rank Organisation, set up a Foundation to donate prizes for research work done in the two fields which most interested him — nutrition (from Rank's start in flour milling) and opto-electronics (from his later work in the film industry).

This year, one of the prizes was split between seven researchers for their work on liquid crystal tv screens. This is a classic example of a seminal invention being made in the West, but exploited in the Far East.

The pioneering work on lcd screens was done by Thomas Peter Brody, while at Westinghouse in America. He headed a team of thirty who found out how to deposit thin film transistors on a flat panel and so directly address individual cells of a liquid crystal display.

Ten years later research done at the Royal Signals and Radar Establishment at Malvern and the University of Dundee showed that amorphous silicon, as developed for solar cells, was the best material to use for making the thin film transistors. Amorphous silicon is non-crystalline, and much easier to apply evenly over large areas. But neither Malvern nor Dundee had the resources to create panels suitable for the consumer market.

Westinghouse had succeeded, as far back as 1972, in making a 15 by 15cm square panel, with 12,000 elements. Five years later Westinghouse made a panel with 30,000 elements. They were suitable for computer graphics and text. But then the company lost interest in lcd screen technology; the original work had been funded by government military contract and Westinghouse was not interested in consumer applications.

In 1981 Brody left Westinghouse and set up his own company, Panelvision, with sights set on the computer and tv market. By 1984 Panelvision had made a 25cm diagonal display with 256,000 elements, but the company was under-funded. The next year it was bought out by military avionics company Litton Industries. They too were not interested in consumer applications.

By then the Japanese had moved in. The first liquid crystal colour tv screen was made in 1983 by Seiko but the breakthrough came in 1985 when Matsushita (Panasonic) found a way of improving both colour reproduction, and brightness when the picture is viewed off axis. Although obviously bitter about the way Western research has been handed on a plate to Japanese industry for exploitation, Brody is gracious in the way he salutes the Japanese achievement.

"The picture on the Panasonic three inch tv set is as good as you would get from a colour tube," he says.

The Japanese, past masters at production engineering, found a way of accurately mass producing a 7.5cm diagonal screen, made up from 100,000 picture elements divided into triplets of red, green and blue. Most important, they realised the need to tune the thickness of the liquid crystal material to the wavelength of the light.

Because red, green and blue light have different wavelengths, the red, green and blue cells each have different dimensions, matched to the wavelength of red, green and blue light.

Says Brody, "You ain't seen nothing yet — I believe this is the start of another major solid state revolution, comparable to the transistor in economic impact."

I asked Brody about the popular notion that before long television sets will have flat lcd colour panels that you hang on the wall. "In the end that is inevitable," he told me. "But it's a long, long way off. The large screen colour tube will be the last thing to be replaced."

The tv industry clearly shares Brody's faith in the colour tube as we now know it. Sony is investing in expanded tube production at its crt plant at Bridgend, Wales. On the day that three of its lcd engineers shared the Rank prize with Peter Brody, Matsushita announced that it was spending \$160 million on a new factory to build cathode ray tube colour screens at Troy in Ohio, USA. This plant will be jointly owned by Matsushita and Philips, under a joint venture deal signed way back in 1952. Significantly, however, tube production at Troy will be centred on 74cm and 84cm crts, rather than the smaller sizes for portable sets which are more likely to be replaced by lcds.

"The future of lcd is in new applications for which tv tubes aren't suitable," says Brody. "Already in Japan they are making two or three million pocket tv sets a year. The next step will be to make pocket sets with larger screens, 13cm diagonal instead of 7.5cm. Then there's the computer market. In three or four years computers will be using colour lcd screens instead of colour tubes."

"It will take that long because remember you are not talking about integrated circuits, where you keep doubling the amount of elements, and all along you have something to sell. Here you have nothing to sell until you have a screen with around 100,000 elements. For high definition computer graphics, you need about 1.5 million lcd elements, half a million blue, half a million red and half a million green, all accurately arranged in triplets.

"Already the Japanese are planning to put a flip down lcd tv screen on each seat in their Bullet train. Airlines are doing the same. In the future every telephone will have one. Although high quality moving pictures won't go down an ordinary telephone line, you can build up still images slowly."

The list of applications is endless. Lcd screens will be used in cars to display engine functions. Already flat panels are being used on aircraft flight decks, for navigation and instrumentation display.

The Panasonic pocket tv, which has 100,000 elements, has been selling in Japan for two years now, for around 60,000 yen (£250). They should be in British shops in time for this Christmas.

Already Panasonic has gone a stage further, by building a tv projector using the same screen display as the pocket tv. A bright light is shone through the lcd panel and the image focussed on a wall screen by a projection lens.

Peter Brody, having seen two employers lose interest and fail in the lcd business, has now started a third company of his own. He acts as a consultant for computer manufacturers, like Apple, which will eventually use lcd screens. Brody is understandably pretty sour.

"There is a saying in America about

Continued on page 18

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KICKING THE BUCKET

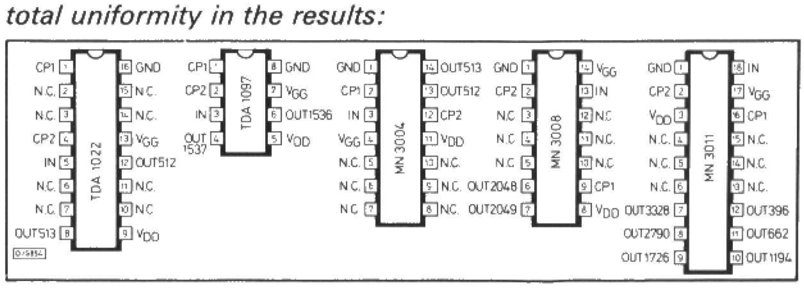
It seems only yesterday I first praised the new TDA1097 Bucket Brigade Delay chip. In fact, I think it was introduced in 1983.

Until then probably the most common delay chip used was the TDA1022 whose arrival in about 1977 had enabled solid state electronics to replace mechanical spring line units. The TDA1022 had its drawbacks in that it was a bit noisy, attenuated the signal, and had a maximum usable delay of only 51ms. The TDA1097 was much quieter, didn't reduce the signal level and had a delay of 153ms.

Sadly, the manufacturers, Mullard, have now dropped both chips. Even though digital techniques are well capable of delaying audio signals for echo, reverb and so on, bbds have the big advantage of simplicity and cheapness. It is hard to understand why Mullard should find them uneconomic, though Reticon seem to think similarly as their SAD1024 is no longer available either.

Happily, all is not lost for the analogue effects constructor for at least Panasonic appear intent on keeping their range of bbds. Their MN3004 has the same 512 stages as the TDA1022, and the MN3008 with its 2048 stages is near enough equal to the TDA1097's 1536. Alternatively there is the MN3011 with its 3328 stages and six output taps. But unfortunately for designs already published, these chips are not pin-compatible with the Mullard bbds. This means that although existing circuits can probably use the Panasonic chips in place of the Mullard ones, connections on pcbs will have to be rerouted.

If any of you are building a Mullard bbd type project but can't find the chips (though some suppliers still have stocks — ring me and I'll tell you who) and want to try using the Panasonic ones instead, the pin-outs are below, though I cannot guarantee total uniformity in the results:



Mullard have changed in other respects as well — in fact they are no longer called Mullard. The company was founded in 1920 by Stanley Mullard and continued to trade under his name even after they became part of the Philips group in 1927. Since April, though, they have been called Philips Components Ltd, which name, the company believe, will enhance their international image. With eight plants in the UK and around 8000 employees we hope they will continue to produce products like tv tubes, semiconductors, capacitors and other familiar devices.

We are sorry that a household name like Mullard should cease to exist, but if times have to change who can delay them?

THE EDITOR

SPEAKING CLOCK

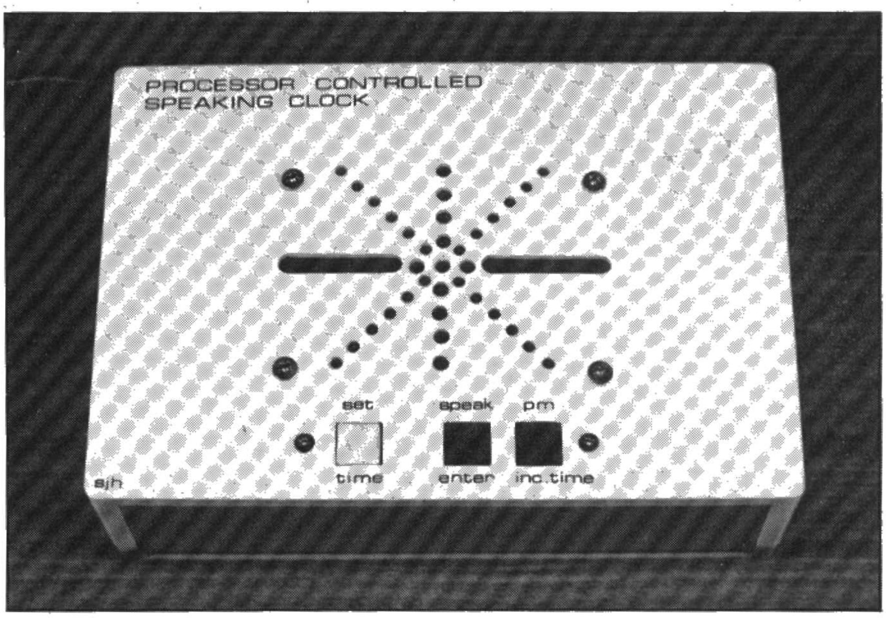
BY STEPHEN HUNT

I SPEAK YOUR DATA

In the beginning was the Word ... and time began. Seconding the SPO256AL speech chip to verbalise the output of a real-time clock may be a less momentous event, but it continues an ancient and honourable tradition!

Many articles have been designed around the SPO256AL speech synthesiser. However, the majority of them have been simply for experimentation in conjunction with a home computer and serve no real application. This article describes how the allophone speech system can be used to produce a speaking clock which may be invaluable to a blind person or simply a novelty clock demonstrating the use of current electronic devices.

The block and circuit diagrams are shown in Fig.1. The system forms a simple microprocessor controller which is used to process data from the real time clock. The speaking clock uses a 6802 micro-processor in conjunction with a 2716 eprom, 6821 pia and an ICM7170 real time clock. The heart of the system is the program stored in the rom.



MEMORY MAP

The eprom occupies locations 8000H to 87FFH (2K). The address decoding for IC3 uses A15 via an inverter IC6a when the eprom is enabled low. The pia, IC2, is selected by A14 and A2, corresponding to location 4004H. To prevent the pia and eprom being selected at the same time A15 is also connected to CS2. RS0 and RS1 are connected to A0 and A1 respectively and are used to select internal registers which control port operations. The pia places the speech synthesiser in the memory map.

It might appear at first that using a pia to interface with IC4 and a few switches is over complicating matters. Alternatively, octal buffers such as the 74LS244 type of devices could be used but would require extra decoding logic, take up more room and cost more. The 6821 has three select lines (CS0, CS1 and CS2) which can be connected to appropriate address lines to place it in the memory map, and allows for a much simpler approach. The 6821 also contains two user ports, A and B which can be set by software as inputs or outputs as required. The speaking clock program requires PA0 to PA6 to be outputs and PA7 to be an input line. Port B lines are all set as inputs. Port A controls the

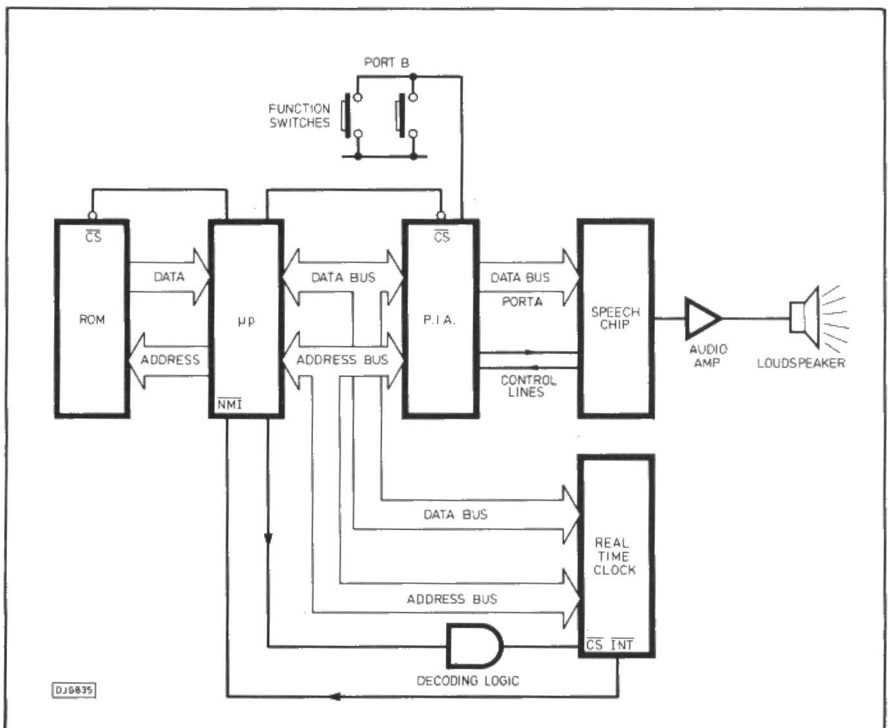


Fig.1. *Block diagram for the speaking clock*

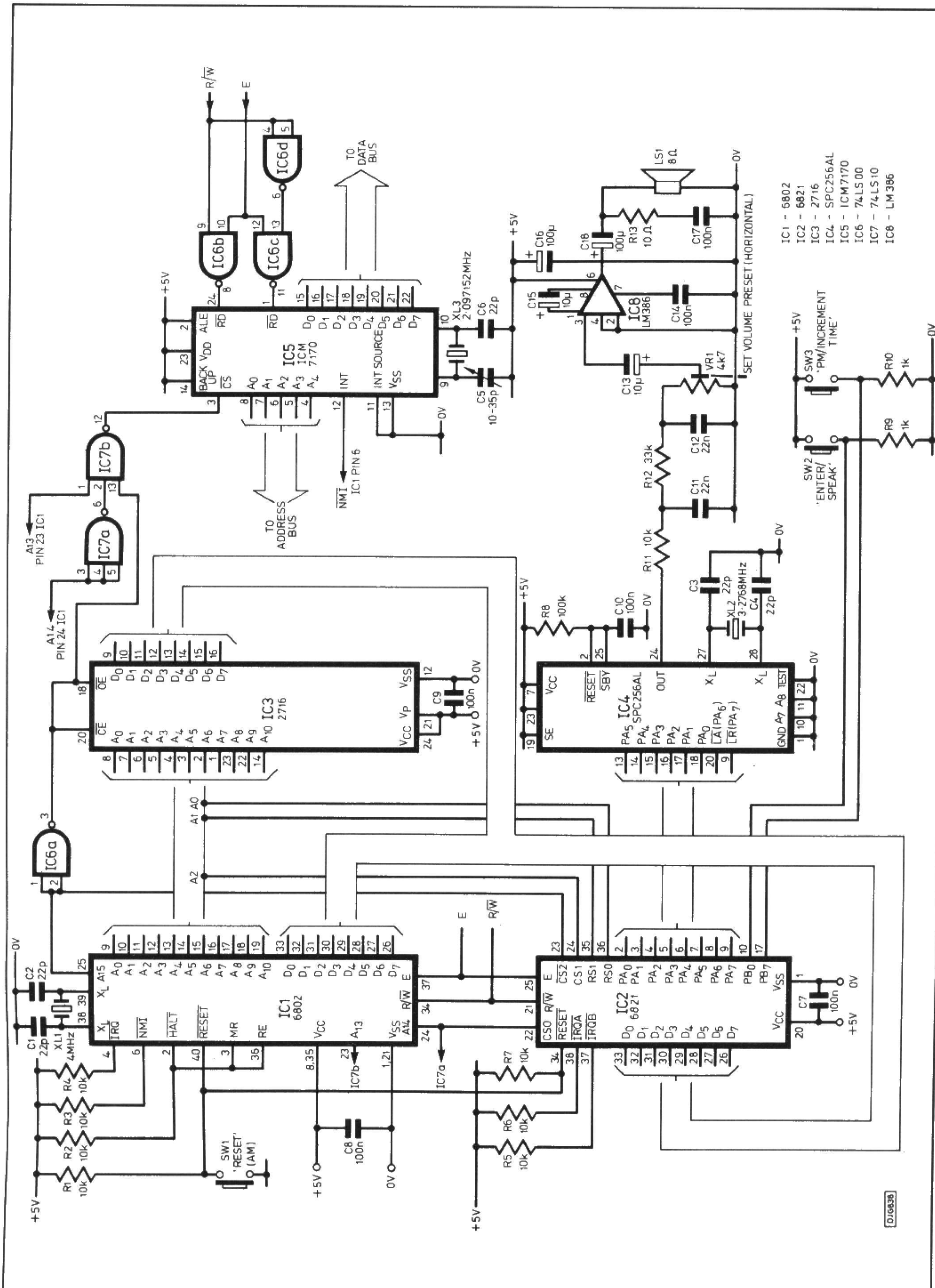


Fig.2. *Circuit diagram for the speaking clock*

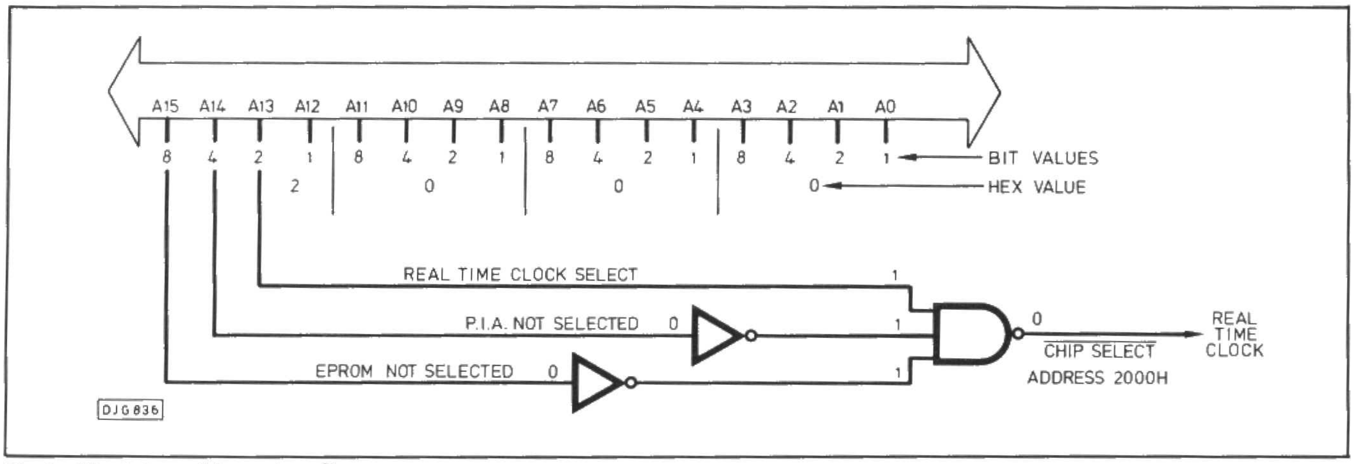


Fig.3. *Obtaining address decoding*

speech synthesiser while port B looks at the function switches, S2 and S3.

The real time clock, IC5, sits at location 2000H and is selected by IC7 from address lines A13, A14 and A15. Fig.3 shows how the decoding is obtained. All other decoding is done in a similar way.

The speaking clock uses a small amount of ram for data storage and as a stack for holding return addresses when jumping to subroutines. This ram is contained within the 6802 at locations 0000 to 007FH (128 bytes).

It should be realised that the devices are only partially decoded and therefore appear in several blocks in memory. However, as only three locations are decoded in the 64K area, this causes no problems of accidental enabling and is therefore perfectly acceptable.

SPEAK TO ME

Words are generated by stringing together allophones which make up the basic sounds of speech. By carefully selecting them a fairly reasonable quality of speech can be produced bearing in mind the limitations when compared to digitally encoded voice systems.

The data control (handshaking) is performed by two lines, load address and load request. When the synthesiser is ready for data the load request line is held low. Then the allophone data is placed onto the bus and by taking the load address low latches the data into the chip. While it is speaking (busy) the load request line is taken high and only when it goes low again can you send the next data. The processor looks at PA6 and PA7 of IC2 to control the data flow.

The speed or pitch at which it speaks is governed by XL2. The prototype used a 3.2768 MHz crystal but any value in the range of 3 to 3.5 MHz will do. The output from IC4 is pulse width modulated at 20kHZ and this is removed by a low pass filter formed by R11, C11, R12 and C12. The resulting audio is then amplified by a small power amplifier, IC8, to drive a loudspeaker.

No allophone data has been given here as many readers will have probably come across this device before. *(Allophone Data Principles were discussed in the MicroChat article in PE Sept–Oct 87. Ed.)*

KEEPING TIME

In order to keep track of the time a real-time clock is used. This device contains an onboard oscillator and a series of registers which contains data for hours, minutes, seconds etc. These registers are simply cascaded up-counters, ie, the seconds counter sequences from zero to sixty then the carry-out from this counter increments the next, which in this case is the minutes. The counters can be preloaded to any value before the oscillator is enabled. Each register has an address and by sending data to that address the counter is loaded. The hours counter is a programmable divider which can be set by software to divide by 12 or 24 (12 or 24 hour mode). The real-time clock is completely independent from the processor and is free running. The processor simply preloads the registers with time data and starts the clock. By reading the register addresses the processor can obtain the time which the program then sorts out to provide the speech synthesiser with word data.

When the processor has finished reading data from the real-time clock it scans the function switches. Not exactly doing too much, is it? This may seem rather a waste of processing power. Alternatively, you could use the processor to keep time by using its internal registers as programmable dividers. This however, requires several processor registers which are not being used for data manipulation and as the 6802 has only three working registers this is not feasible. The use of a real-time clock reduces the program length and complexity substantially.

The ICM7170 real-time clock was chosen mainly because it is easy to use. It is completely software controlled and has a total of 18 internal registers. The main register of interest is the command register which is used to set up operation modes. Table 1 shows the assigned bits.

Bits D0 and D1 set the internal clock frequency. In the prototype a 2.097MHz crystal was used but others can be accommodated by making the program changes shown in Table 2.

D2 is set to zero for 12 hours. Stopping and starting of the clock's counters is obtained by writing a 0 or 1 respectively into the bit location. D4 sets up interrupts for alarms and D5 is used as a test bit which clocks the counters at a faster rate. D5 and D7 are not used.

D7	D6	D5	D4	D3	D2	D1	D0
—	—	TEST	INT	RUN	12/24	FREQ	FREQ

Table 1

CRYSTAL FREQ	D0	D1	PROGRAM CHANGES
32.768KHZ	0	0	0010 00 04BC 08
1.048576MHz	0	1	0010 01 04BC 09
2.097152MHz	1	0	AS IN HEX LIST
4.194304MHz	1	1	0010 03 04BC 0B

Table 2

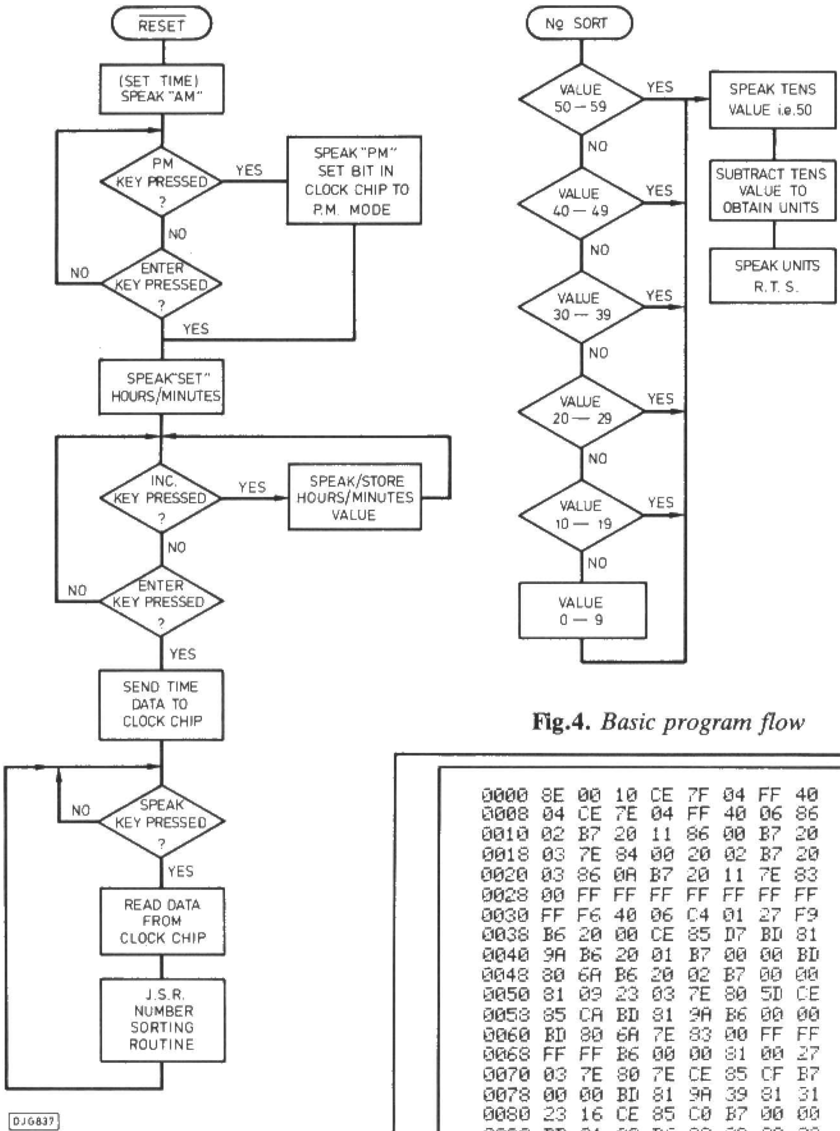


Fig.4. *Basic program flow*

```
0000 8E 00 10 CE 7F 04 FF 40
0008 04 CE 7E 04 FF 40 06 86
0010 02 B7 20 11 86 00 B7 20
0018 03 7E 84 00 20 02 B7 20
0020 03 86 0A B7 20 11 7E 83
0028 00 FF FF FF FF FF FF FF
0030 FF F6 40 06 C4 01 27 F9
0038 B6 20 00 CE 85 D7 BD 81
0040 9A B6 20 01 B7 00 00 BD
0048 80 6A B6 20 02 B7 00 00
0050 81 09 23 03 7E 80 5D CE
0058 85 CA BD 81 9A B6 00 00
0060 BD 80 6A 7E 83 00 FF FF
0068 FF FF B6 00 00 81 00 27
0070 03 7E 80 7E CE 85 CF B7
0078 00 00 BD 81 9A 39 81 31
0080 23 16 CE 85 C0 B7 00 00
0088 BD 81 9A B6 00 00 80 32
0090 81 00 27 03 7E 80 DE 39
0098 81 27 23 11 CE 85 B7 B7
00A0 00 00 BD 81 9A B6 00 00
00A8 80 28 7E 80 90 81 1D 23
00B0 11 CE 85 AE B7 00 00 BD
00B8 81 9A B6 00 00 80 1E 7E
00C0 80 90 81 13 23 11 CE 85
00C8 A2 B7 00 00 BD 81 9A B6
00D0 00 00 80 14 7E 80 90 81
00D8 09 23 03 7E 81 34 81 09
00E0 27 28 81 08 27 1E 81 07
00E8 27 26 81 06 27 28 81 05
00F0 27 2A 81 04 27 2C 81 03
00F8 27 2E 81 02 27 30 CE 85
0100 00 7E 81 9A CE 85 32 7E
0108 81 9A CE 85 38 7E 81 9A
0110 CE 85 29 7E 81 9A CE 85
0118 21 7E 81 9A CE 85 1A 7E
0120 81 9A CE 85 14 7E 81 9A
0128 CE 85 0D 7E 81 9A CE 85
0130 07 7E 81 9A 81 0A 27 26
0138 81 0B 27 28 81 0C 27 2A
0140 81 0D 27 2C 81 0E 27 2E
0148 81 0F 27 30 81 10 27 32
0150 81 11 27 34 81 12 27 36
0158 CE 85 97 7E 81 9A CE 85
0160 3F 7E 81 9A CE 85 46 7E
0168 81 9A CE 85 50 7E 81 9A
0170 CE 85 5A 7E 81 9A CE 85
0178 64 7E 81 9A CE 85 6D 7E
0180 81 9A CE 85 78 7E 81 9A
0188 CE 85 83 7E 81 9A CE 85
0190 8F 7E 81 9A FF FF FF FF
0198 FF FF 86 40 B7 40 04 A6
01A0 00 81 FF 26 01 39 A6 02
01A8 F6 40 04 C4 80 27 03 7E
01B0 81 A8 08 B7 40 04 7E 81
01B8 9A FF FF FF FF FF FF FF
0300 F6 40 06 C4 01 27 F9 B6
0308 20 00 B6 20 01 B7 00 00
0310 84 80 27 25 B6 00 00 80
0318 80 B7 00 00 81 0C 27 2E
0320 81 05 23 2A CE 86 10 BD
0328 81 9A CE 85 D7 BD 81 9A
0330 B6 00 00 BD 80 6A 7E 80
0338 4A CE 85 F0 BD 81 9A CE
0340 85 D7 BD 81 9A B6 00 00
0348 BD 80 6A 7E 80 4A B7 00
0350 00 CE 85 FE BD 81 9A CE
0358 85 D7 BD 81 9A B6 00 00
0360 BD 80 6A 7E 80 4A FF FF
0400 CE 86 B0 BD 81 9A F6 40
0408 06 C4 80 26 33 F6 40 06
0410 C4 01 27 F2 7F 00 06 CE
0418 86 C1 BD 81 9A 4F F6 40
0420 06 C4 01 26 29 F6 40 06
0428 C4 80 27 F2 81 0B 23 03
0430 7E 84 1D 4C B7 00 00 BD
0438 80 6A B6 00 00 7E 84 1E
0440 CE 86 B8 BD 81 9A 86 80
0448 B7 00 06 7E 84 17 B6 00
0450 00 F6 00 06 1B B7 20 01
0458 CE 86 CE BD 81 9A 4F B7
0460 00 00 BD 80 6A F6 40 06
0468 C4 01 27 03 7E 84 85 F6
0470 40 06 C4 80 27 EF B6 00
0478 00 81 28 23 03 7E 84 5E
0480 8B 0A 7E 84 5F B6 00 00
0488 B7 00 05 4F B7 00 00 BD
0490 80 6A F6 40 06 C4 01 27
0498 03 7E 84 B1 F6 40 06 C4
04A0 80 27 EF B6 00 00 81 08
04A8 23 03 7E 84 8B 4C 7E 84
04B0 8C F6 00 05 B6 00 00 1B
04B8 B7 20 02 86 0A B7 20 11
04C0 7E 83 07 FF FF FF FF FF
04C8 FF FF FF FF FF FF FF FF
04D0 FF FF FF FF FF FF FF FF
04D8 FF FF FF FF FF FF FF FF
04E0 FF FF FF FF FF FF FF FF
04E8 FF FF FF FF FF FF FF FF
04F0 FF FF FF FF FF FF FF FF
04F8 FF FF FF FF FF FF FF FF
0500 2E 0F 0B 04 04 04 FF 0D
0508 1F 04 04 04 FF 1D 0E 13
0510 04 04 04 FF 28 3A 04 04
0518 04 FF 28 06 28 04 04 04
0520 FF 37 0C 08 37 04 04 04
0528 FF 37 07 23 0F 0B 04 04
0530 04 FF 14 11 04 04 04 FF
0538 38 06 0B 04 04 04 FF 0D
0540 07 0B 04 04 04 FF 13 2D
0548 07 28 0B 04 04 04 FF FF
0550 0D 2E 07 3E 23 04 04 04
0558 FF FF 1D 33 0D 13 0B 04
0560 04 04 FF FF 28 3A 0D 13
0568 0B 04 04 04 FF 28 0C 28
0570 0D 13 0B 04 04 04 FF FF
0578 37 0C 08 37 0D 13 0B 04
0580 04 04 FF 37 07 23 07 0B
0588 0D 13 0B 04 04 04 FF 14
0590 0D 13 0B 04 04 04 FF 38
0598 06 0B 0D 13 0B 04 04 04
05A0 FF FF 0D 30 07 0B 0D 13
05A8 00 04 04 04 FF FF 1D 33
05B0 0D 13 00 04 04 04 FF 28
05B8 3A 0D 13 00 04 04 04 FF
05C0 28 0C 28 0D 13 00 04 04
05C8 04 FF 35 04 04 04 FF 2A
05D0 2D 18 02 29 04 04 FF 00
05D8 12 13 04 0D 06 10 04 0C
05E0 0C 37 04 04 04 FF FF FF
05E8 FF FF FF FF FF FF FF FF
05F0 24 1F 15 00 04 10 3A 0B
05F8 0C 2C 04 04 04 FF 24 1F
0600 00 15 04 3B 28 11 33 0B
0608 1F 0B 04 04 04 FF FF FF
0610 24 1F 00 15 04 13 28 0B
0618 0C 2C 04 04 04 FF FF FF
06B0 14 04 07 10 04 04 04 FF
06B8 09 13 04 07 10 04 04 04
06C0 FF 37 07 11 04 20 33 37
06C8 04 04 04 FF FF FF 37 07
06D0 0D 04 10 0C 0B 0C 01 0D
06D8 02 37 04 04 04 04 FF FF
07F8 FF FF FF FF FF FF 80 00
```

Fig.5. *Hex dump of the speaking clock program*

The ICM7170 was not specifically designed for the 6800 series of microprocessors. The device has both active-low read and write lines. IC6B to IC6D gate the processor's E line with the r/w line to provide IC5 with the required RD and WR signals. A simple inverter cannot be used between the two lines as this would not take into account the r/w timing cycle. In order to synchronise the r/w signals with the processors clock, 02 of the clock cycle ('E' line) is also gated with the r/w line.

PROGRAM OPERATION

After switching on you need to set up the time. By pressing 'SET TIME' the clock will say "AM". Pressing 'INC' sets to pm, or pressing 'ENTER' causes it to say "SET HOURS". By pressing 'INC' the hours are spoken in turn (1 to 12). When the required hour has been spoken pressing 'ENTER' stores this value in the hours register. It then says "SET MINUTES". Pressing 'INC' then advances the tens of minutes (10, 20, 30, 40, 50). When the required value has

been spoken pressing 'ENTER' stores this value in a location in ram. Pressing 'INC' now advances the units (1 to 9). Pressing 'ENTER' stores this value in a second location in ram. Adding these two locations together gives the total minutes value which is then stored in the minutes register. The program now jumps to a routine which looks to see if the 'SPEAK' key has been pressed.

On pressing the 'SPEAK' key the 100ths second register is read. This latches the time data to prevent it rolling when reading the various time data registers. The hours register is read and the program jumps to another routine which determines the hour value. Having done this it now jumps to the next routine which sends the required word data to the speech synthesiser. Now the clock has to speak the minutes. To explain this it is best to look at an example.

Suppose the minutes value is 46, the routine determines the group value, which in this case lies between 40 and 49, and so "forty" is sent to be spoken. To obtain the unit value (six) forty is subtracted and "six" is sent to be spoken. Fig.4 shows the program flow.

A routine also sorts out the grammar. If the minute value is less than ten "OH" has to be spoken before the units value and if zero it has to say "O'CLOCK". *(Was Victor Borg consulted about the correct pronunciation of the apostrophe? Ed.)*

If the time lies between 1:00am to 11:59am it will say "GOODMORNING THE TIME IS.....". Between the times of 12;00noon to 5:00pm it says "GOODAFTERNOON THE TIME IS....." and from 6:00pm onwards it says "GOODEVENING THE TIME IS.....".

The machine code listing is shown in Fig.5 and occupies approximately 1K of code. If any readers might like to enhance or write their own programs, the addresses in Table 3 may be of use.

	REGISTERS	ADDRESS
REALTIME CLOCK	1/100THS	2000H
	HOURS	2001H
	MINUTES	2002H
	SECONDS	2003H
	MONTHS	2004H
	DATE	2005H
	YEAR	2006H
	DAYOFWEEK	2007H
	COMMAND REGISTER	2011H
SPEECH SYNTHESISER		4004H
FUNCTION SWITCHES		4006H

Table 3

FINDING THE STORED PROGRAM

When the processor is reset it looks at the reset vector addresses FFFEH and FFFFH and reads the data at each location. These two bytes are loaded into the processor's program counter and is used as a start location from which to run. As the eprom sits at memory location 8000H this must be the address held in the program counter.

On looking at the hex listing we see that the reset vector address is stored in locations 07FEH and 07FFH and not the required addresses FFFEH and FFFFH! This is easily explained. As the eprom is only 2K * 8 (16K) address lines A0 to A10 are all that are needed to access any location within it. Therefore the bit values A11 to A14 are not seen (A15 selects the eprom). When FFFEH is sent out by the processor A11 to A14 are 'lost' and the processor sees the contents of address 07FEH instead. This is of no consequence as long as the processor obtains the correct start location.

CONSTRUCTION

A suggested power supply is shown in Fig.6.

The majority of components fit onto a double sided pcb, the layout of which is shown in Fig.7. It is recommended that sockets are used for all ic positions, especially IC3 which may be required to be replaced with different versions of software. Also note the capacitor polarities around IC8. A soldering iron with a small bit is required for construction as many tracks run extremely close together and are very easily bridged by solder. Before fitting any components to the pcb make all the through hole connections using fine single strand wire. *(Better still, use pc link pins. Ed.)* Care should be taken to ensure all these connections are made as there are quite a few, many being under components. Construction can now continue in the usual manner.

The unit was housed in a Verobox type 75-1411D. The back panel is used as a chassis onto which the transformer is bolted. It also serves as a heatsink for the regulator (IC9). The mains lead passes through a grommet and is secured by a 'P' clip fixed to the base of the box. The earth wire is soldered to a tag bolted to the transformer fixings. A few 3mm holes are drilled in the base under the transformer to aid ventilation.

The pcb is fixed to the base by spacers. Make sure that the far side of the pcb sits flush against the back panel so that the regulator can be bolted to it. Terminal pins should be used where wires connect to the board. This makes the board easier to remove, and looks neater.

The speaker is attached using four M4*10 csk screws. The speaker should be as large as possible (at least 3in) to provide a good frequency response. Rub on transfer letters can be used to label switch functions and lacquer applied to fix them.

TESTING

After checking the board construction and wiring connect a voltmeter (set to 10V range) across C19. The rough dc should be around 7.5V (minimum). Check from 5V on the output of IC9. Press 'SETTIME'. It should respond by saying "A M". If nothing happens recheck your wiring. If you programmed your own eprom check it for errors. Also make sure that the rom is being addressed (selected) by monitoring IC3s chip-select pin, which should be low. (A15 should be constantly high).

Adjust C5 to obtain an accurate clock time. By trial and error an accuracy of few seconds a day is possible. An alternative method is to write a piece of software which causes the realtime clock to produce an interrupt every second. The interrupt signal can then be monitored with a frequency counter (negative side triggered) and C5 adjusted for a reading of 1.0000000 on the display. The first method is accurate enough although more time consuming.

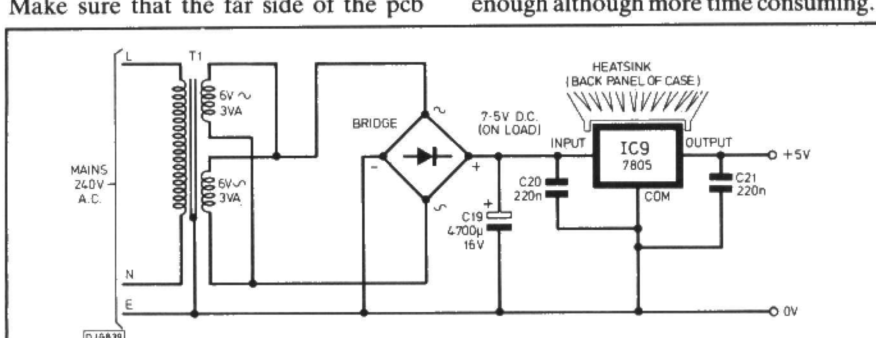
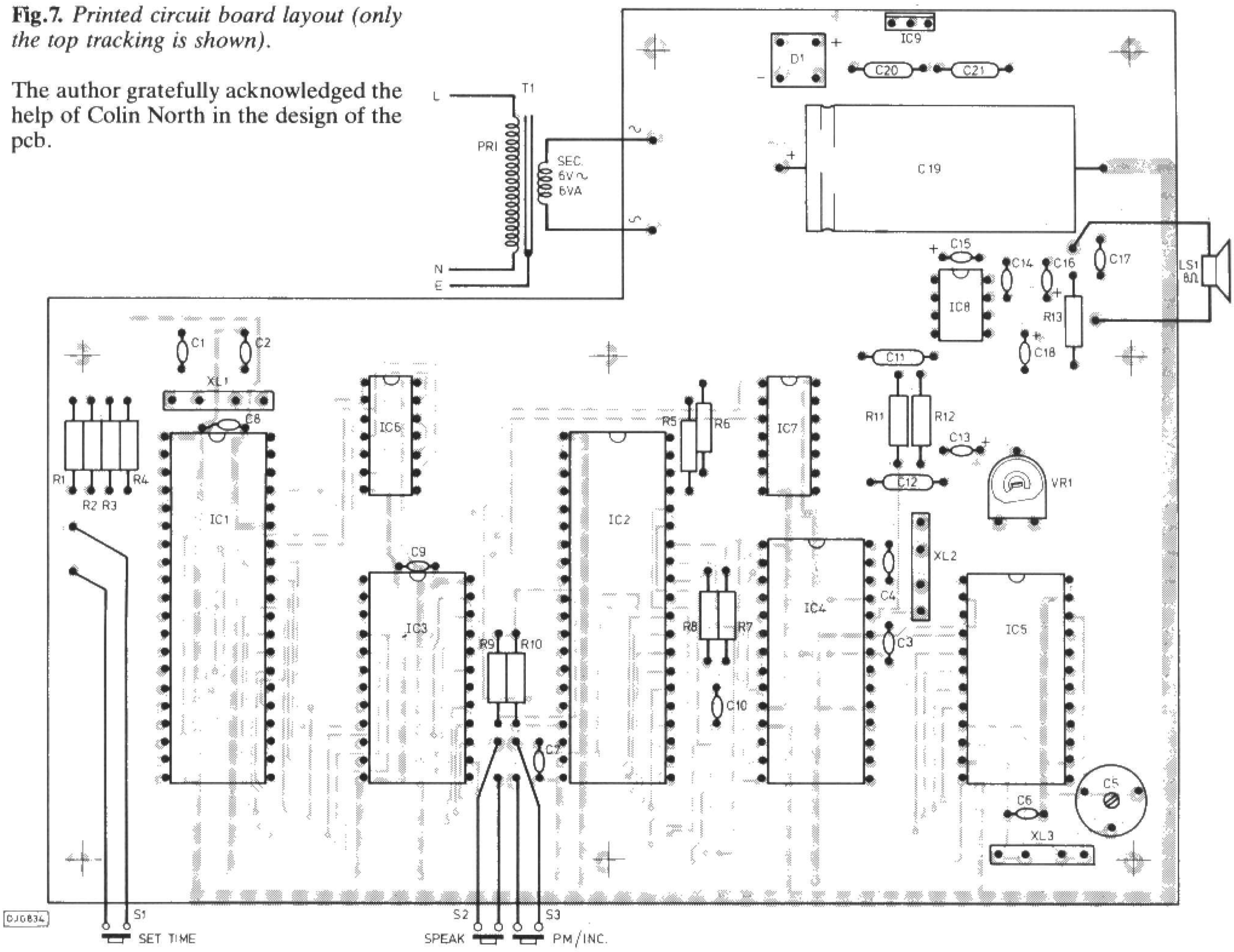


Fig.6. *Power supply circuit diagram*

Fig.7. *Printed circuit board layout (only the top tracking is shown).*

The author gratefully acknowledged the help of Colin North in the design of the pcb.



COMPONENTS

RESISTORS

R1–R7	10k (8 off)
R9,R10	1k (2 off)
R8	100k
R12	33k
R13	10Ω

All resistors ⅓W 5%.

CAPACITORS

C1–C4,C6	22pF ceramic (5 off)
C5	10–35pF variable
C7–C10,C14,C17	100nF ceramic (6 off)
C11,C12	22nF polyester (2 off)
C13,C15	10µF 16V elect (2 off)
C16,C18	100µF 16V elect (2 off)
C19	4700µF 16V elect
C20,C21	220nF polyester (2 off)

SEMICONDUCTORS

D1	Bridge rectifier 2A 50V
IC1	6802
IC2	6821
IC3	2716 (5V)
IC4	SPO256AL
IC5	ICM7170
IC6	74LS00
IC7	74LS10
IC8	LM386 (6V version)
IC9	7805

POTENTIOMETER

VR1	4k7 horiz preset

CRYSTALS

XL1	4MHz
XL2	3 to 3.5MHz (see text)
XL3	(see text)

MISCELLANEOUS

T1	0–6V, 0–6V transformer 3VA per winding
S1,S2,S3	SP push make switches (3 off)
Case	Vero type 75-1411D (20.5 × 14 × 7.5cm)
LS1	8 ohm 3in speaker

Pcb, sockets, wire etc.

CONSTRUCTOR'S NOTE

One of Stephen's friends has very kindly offered to program any blank eproms sent to him in connection with this project. Send your eprom with a stamped addressed envelope (or equivalent return postage) to:

Charles Moore,
101 Heatherstone Avenue,
Dibden Purlieu, Hythe,
Hants. SO4 5LE.

(please state value of crystal being used in the real-time clock).

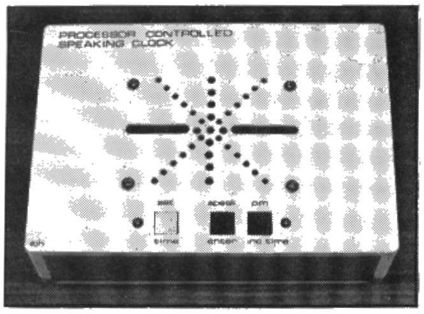
CONSTRUCTOR'S NOTE

The double sided printed circuit board is available through the PE PCB Service, see page 60.

STEPHEN HUNT

While preparing Stephen's article for publication, we were distressed to learn of his tragic death. It is his parent's wishes that we should still publish his article. We send our deepest sympathy to his family. Ed.

If you are unable to set up the clock fairly accurately then this is probably due to the crystal not being loaded correctly. Inserting the specified load capacitor (C6) for the crystal should cure the problem. Finally set VR1 to the volume required.



STATIC SENSITIVE

During bench testing of the prototype, it was discovered that the realtime clock's interrupt pin was prone to static charges. When "zapped", the chip latches up and draws excessive current.

This is due to the fact that the interrupt line does not have the normal protection diodes found in most cmos devices. As long as the relevent pcb tracks are not touched by "aerials" such as screwdrivers etc, no harm should result.

It was felt that adding components to suppress transients could prove to be more trouble than it's worth and as these components are not integrated on the silicon itself would only provide limited protection. However, once the board is housed in an enclosure the chance of latch up is reduced to zero. The prototype has been working faultlessly for many months.

Please take care when bench testing! PE

"....And this model has a vocal output!"

LEADING EDGE

continued from page 8

how pioneers end up with arrows in their back," he recalls.

Brody has ideas of his own about how to build a very big lcd display. "But I am trying to raise money so I am not yet ready to talk about it."

The oddest part of the story relates to the patents on lcd colour screens.

"Westinghouse filed for a patent on Fisher's idea of putting a thin film of transistors and liquid crystal cells on glass, covering them with colour triplet filters, and viewing the image with transmitted white light, such as a white fluorescent back light," says Brody. "This is what the Japanese are now doing. And they are infringing the Westinghouse patent. Westinghouse say they are not in the panel business so do not want to spend the money on legal action. Our own company, Panelvision, had exclusive rights on the patents and we tried to enforce them. The International Trade Commission in Washington said they would block the import of lcd sets into North America if we could prove they infringed the patents. But Panelvision went out of the lcd business and now no-one is enforcing the Westinghouse patent, even though it has several years left to run."

To add some further detail I searched out the key patent, USP 3 840 695. It was filed by Westinghouse, in October 1972 and granted two years later. Under US law it will remain in force until 1991. It was Westinghouse researcher Albert Fischer who hit on the key idea of coating glass with a thin film matrix of transistors and liquid crystal cells, and covering them with a matching matrix of tiny red, green and blue filters.

Westinghouse claimed in the patent to have solved the problem of providing 750,000 colour cells. But despite spending hundreds of millions of dollars on the project, they never succeeded in making a saleable product for consumer use. PE

PROXIMITY DETECTION

BY THE PROF

GREET YOUR INTRUDERS WITH A WAVE

Emissary emanations of etherical electromagnetism emit information about uninvited interlopers – usually in the form of a loud audible alarm. Select from rf, radar, ultrasonic or infra-red for starters.

A great many applications require that the presence of something, or more usually someone, must be detected. Typical applications are burglar alarms, automatic lighting, and automatic cutouts that operate if (say) someone gets too close to a dangerous piece of machinery while it is operating. Circuits of this type come under the general heading of "proximity detectors", or "presence detectors" as they are alternatively known these days. There must be almost countless ways of detecting the presence of someone by electronic means, but some of these are rather out-of-date now, or at the other extreme require advanced electronics that takes them beyond the scope of most amateur electronics enthusiasts. This still leaves a substantial number of systems that are of interest to the electronics hobbyist, and in this article we will consider three of these.

GOING TO GROUND

One of the earliest systems of proximity detection (possibly the earliest) is the type which uses an arrangement of the type shown in the block diagram of Fig.1. Although this is not exactly the most modern approach, it still represents one of the more interesting methods.

The l-c oscillator is at the heart of the unit, and this must have a feedback control that permits very accurate control of the positive feedback level. The degree of feedback used must be such that the circuit is only just able to sustain oscillation. One end of the l-c tuned circuit must be connected to earth (or "ground" if you prefer the Americanism). By this I do not just mean that it must be connected to the earth rail of the detector circuit — it must be literally connected to earth. If the unit is mains powered then the mains earth connection should suffice. If not, then a short wave radio style earth connection with a rod or pipe buried in the ground is needed. Failing this, a "dummy" earth might suffice, as described later in this article. The sensing element is an antenna connected to the non-earth end of the tuned circuit. This can be a length of wire, but in my experience a metal plate seems to offer far better sensitivity.

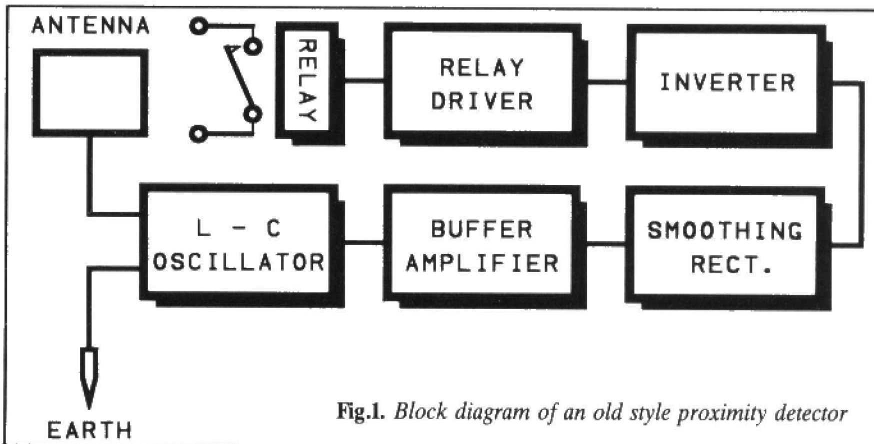


Fig.1. *Block diagram of an old style proximity detector*

This setup may not seem to offer any obvious means of presence detection other than a bit of esp, but it will in fact work quite well, albeit with rather limited operating range. I suppose that there is more than one way of looking at what happens when someone comes close to the antenna, but the generally accepted explanation is that someone close to or actually touching the antenna increases the capacitance from the antenna to earth. This happens due to your body either being earthed, or acting rather like a mini-earth. The effect on the circuit is to slightly damp the tuned circuit so that the level of feedback is no longer able to sustain oscillation. The rest of the circuit must change this lack of oscillation into a switching action that will drive a relay.

The output of the oscillator first feeds into a buffer amplifier. It seems to be very important to have a low level of loading on the oscillator if a reasonable degree of sensitivity is to be obtained. The output from the buffer amplifier drives a rectifier and smoothing circuit, and this normally provides a strong positive dc output signal. However, when oscillation ceases, the output from this circuit quickly drops to zero volts.

Next an inverter/amplifier stage is used to give an output signal that is normally low, but which goes high when the unit is activated. This stage operates the relay via a simple driver stage, and a pair of relay contacts control the load. Normally open contacts are used if the load must be switched on when the unit is activated — normally closed contacts are required if the load must be disabled when the unit is activated.

DETECTOR CIRCUIT

Fig.2 shows the circuit diagram for a proximity detector of this type. As will be apparent from Fig.2, this form of detector can be remarkably simple, and requires no particularly expensive components.

The oscillator has L1 plus the series capacitance of C3 and C4 as the tuned circuit, with the two capacitors providing a centre-tap on the tuned circuit. TR1 operates in the emitter follower mode, and the tuned circuit is coupled to its input by C2. The output of the amplifier is coupled to the centre-tap by C5. An emitter follower only has about unity voltage gain, and generally has a voltage gain of slightly less than unity. However, there is a small voltage step-up through the tuned circuit, and an emitter follower provides plenty of current gain. This enables the circuit to oscillate quite strongly, but VR1 acts as a variable attenuator at the output of the amplifier. In practice this is backed-off to the point where oscillation is only just sustained.

TR2 is the buffer stage, and is another emitter follower. C6 couples the output of TR2 to a standard rectifier and smoothing circuit based on D1 and D2. The oscillator operates at a frequency of a few hundred kilohertz and the relatively low values for C6 and C7 are more

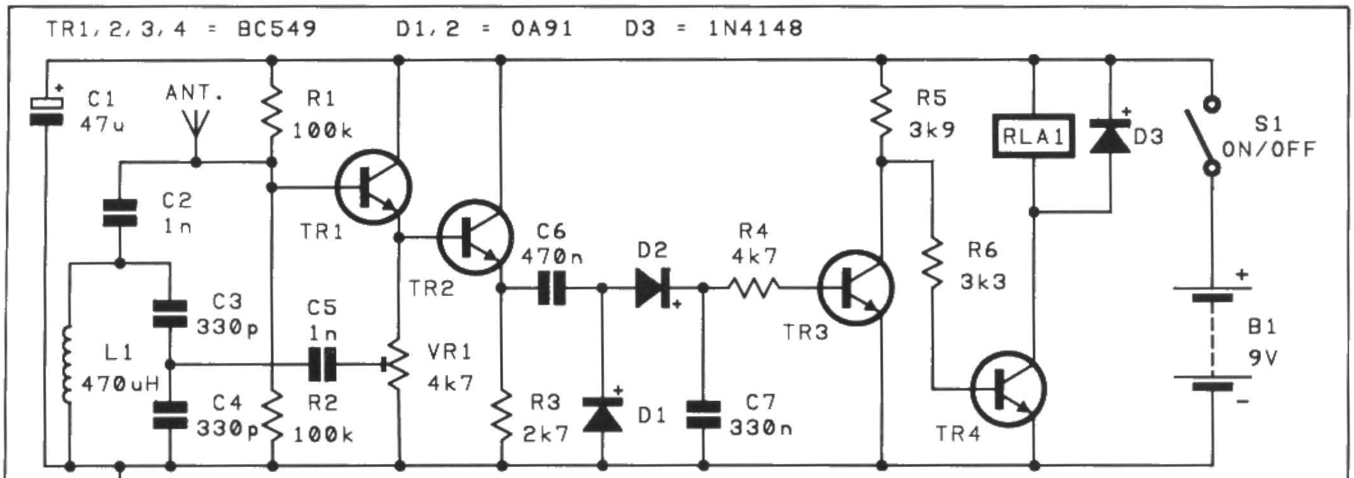


Fig.2. *Proximity detector circuit diagram*

than adequate. TR3 is the basis of the inverter/amplifier stage, which is a simple common emitter switch. This is turned on under normal conditions, but it switches off when oscillation ceases. Its collector voltage then goes to virtually the full positive supply potential. TR4 is the relay driver, and is a second common emitter switch. This is turned on when TR3 switches off, as is the relay that forms its collector load. D3 is the usual protection diode which suppresses the high reverse voltage spike that would otherwise be generated across the relay coil as it was deactivated.

PRACTICAL RESULTS

Although L2 has been specified as having a value of 470μH, any value from about 220μH to 2.2mH seems to give good results. This inductor does not need to be a high Q type, and any rf choke within the specified range should work perfectly well. VR1 needs to be adjusted very accurately if the unit is to achieve good results, and the use of a multi-turn trimpot here is virtually mandatory. An ordinary preset potentiometer might not have sufficient resolution to give satisfactory performance. The relay can be any type which can operate on a 6 volt supply, has a coil resistance of about 200 ohms or more, and which has suitable contacts for your intended application. I used an open construction printed circuit mounting type having a coil resistance of 410 ohms.

I operated the circuit from a 9 volt battery, but anyone using the circuit in earnest would be well advised to use a good quality stabilised mains power supply unit. Any significant variations in the supply voltage are likely to either render the unit insensitive or to produce false alarms. The current consumption under stand-by conditions is only about 5 milliamps or so, but this increases by around 30 milliamps when the relay is activated. The exact increase depends on the coil resistance of the relay, and a high coil resistance is advantageous in keeping down the current drain.

If the unit is powered from a mains power supply, then presumably the mains earth will be connected to the negative supply rail, and will act as the earth for the tuned circuit. You can operate the circuit without an earth, but results then become a little unpredictable, and in general, sensitivity will be reduced. A "dummy" or "artificial" earth will often give good results, and this can just consist of a metal plate beneath the unit, with the antenna above the unit.

The antenna can be a short length of wire, but even with VR1 very carefully adjusted, it is then unlikely that a range of more than a few millimetres will be obtained. Much better results are obtained using a metal plate, such as a sheet of aluminium or a sheet of copper laminate board (as used for printed circuit boards). A plate about 300 by 150 millimetres or larger should give good results. Of course, the antenna must be well insulated from earth if good sensitivity is to be achieved.

Adjusting VR1 is a matter of starting with it set for maximum feedback, and then slowly backing it off until the relay switches on. Then advance VR1 just far enough to cause the relay to switch off again.

This type of proximity detector is strictly a short range device. The best range I could obtain was about 400 millimetres or so. Even this sort of range requires a fairly large antenna plate and careful adjustment of VR1. Obviously some applications do not require very much in the way of operating range. This type of detector could, for instance, be used to detect someone on the other side of a door or window, attempting forced entry. Whereas most systems detect an intruder after entry has been achieved, or during the course of entry, this type of sensor can potentially detect someone as soon as they arrive on the scene. The circuit seems to be perfectly capable of operating through a door or window, incidentally. This type of proximity detector certainly represents an interesting line of investigation for the electronics experimenter, and the cost is extremely low.

ON REFLECTION

Ultrasonics are much used in presence detector type burglar alarms, and these mostly operate on the Doppler shift principle. There are other ways of using ultrasonics for proximity detection, such as broken beam and "radar" style detectors. The latter represents an interesting approach for short and medium range applications. Although it generally offers lower range than a Doppler shift type detector, it has one or two potential advantages for certain applications.

Probably the biggest drawback of an ultrasonic Doppler shift detector is that it is in many ways too sensitive. What is actually detected is not the presence or otherwise of an object, but movement of an object. These alarms seem well able to detect quite small objects, including such things as moths and other insects which may fly into their area of coverage! A radar type detector operates by detecting waves that are reflected back to the receiver, and small objects will simply not reflect back enough signal to be detected, especially at longer ranges. This potentially offers much better reliability at the cost of reduced range and area of coverage.

Where an ultrasonic radar type detector offers the biggest advantage over a Doppler shift type is probably for outdoors use. Anyone who has tried to use a Doppler shift type detector outdoors will be only too familiar with the problems that arise. Problems with insects etc causing false alarms are that much greater, and there are additional problems with the wind causing turbulence that generates false alarms. Even hail, rain, and snow can trigger a Doppler shift detector, as can something like leaves blowing around in the system's field of "view". While a "radar" type detector is not totally immune to these problems, they generally seem to be somewhat less troublesome.

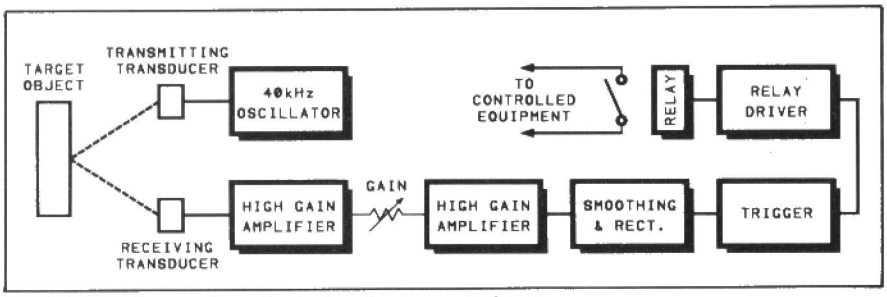


Fig.3. *Block diagram for a "radar" style ultrasonic detector*

A "radar" type system probably works best out of doors where there will normally be a lack of objects to reflect back the ultrasonic sound waves under stand-by conditions. Indoors there will often be a number of objects to produce reflections (such as items of furniture), as well as walls, the ceiling, etc. It is not that a unit of this type will not operate at all indoors, it is more a case of the range often being rather limited. The sensitivity of the system must be kept down to a level that prevents it from being held in the activated state.

Nothing very complex is required for an ultrasonic radar type detector, and the block diagram of Fig.3 shows the basic requirements. A 40kHz oscillator drives the transmitting transducer, which is a standard 40kHz piezo ceramic type, as used in ultrasonic remote control systems. This gives a continuous ultrasonic tone from the transmitter, and if a suitable target object is present, a significant amount of this signal will be reflected back to the receiving transducer. This is again a standard 40kHz ultrasonic transducer of the type intended for remote control applications.

Ultrasonic remote control systems will normally operate at a range of 12 to 15 metres, but such a long range is not practical in this application. The salient point is that in a remote control system the signal only has to go from point A to point B, whereas in a system of this type it also has to make the trip back to point A again. Even with the signal being reflected with 100% efficiency this gives a halving of the range, and in practice a substantial proportion of the signal is likely to be absorbed by the target object. The maximum range is likely to be no more than about four or five metres with co-operative target objects, and much less for small objects or those which have high absorption of ultrasonic waves.

This is sufficient for many applications, but a large amount of gain is needed at the receiver in order to obtain this kind of operating range. In the design featured here around 90dB of voltage gain is provided by a two-stage amplifier. A gain control is included between these two stages, and this is an essential feature. The gain must be as high as possible in order to obtain good range, but must be kept below the point at which the normal level of pick up holds the unit in the activated state.

The output of the second amplifier is fed to a rectifier and smoothing circuit. The positive dc signal this produces is fed to a trigger circuit that provides a high output level if the voltage from the smoothing circuit is above a certain threshold level. The output of the trigger circuit operates a relay via a simple relay driver circuit.

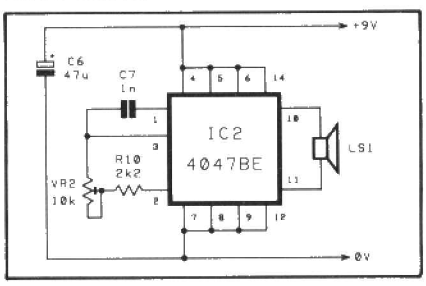


Fig.4. *Ultrasonic transmitter circuit*

CIRCUITS

The transmitter and receiver circuits are shown in Figs.4 and 5 respectively. The transmitter is basically just a cmos 4047BE astable/monostable which is used here in the free running astable mode. Its Q and not-Q outputs drive the transducer (LS1) with anti-phase signals, giving a large peak to peak output voltage. VR2 enables the output frequency to be trimmed to the one at which the two transducers give optimum efficiency.

Two common emitter amplifiers are used at the input of the receiver, with volume control style gain control VR1 being used between these two stages. The output of TR2 feeds into a conventional rectifier and smoothing circuit. The trigger circuit is operational amplifier IC1 connected as a voltage comparator. R7 and R8 provide a reference voltage to the inverting input of a little over 2 volts, and the output goes high when the voltage from the smoothing circuit exceeds this voltage. Common emitter switch TR3 is then turned on, and it in turn activates the relay.

IN USE

Due care needs to be taken with the component layout of this project due to its high level of voltage gain at the receiver and its quite large bandwidth. Also, the input and output of the amplifier are in-phase. The layout must be designed to ensure that there is no obvious path for stray feedback from the input to the output of the amplifier. Consult the retailer's literature to ascertain whether the transmitting and receiving transducers are identical, or there are different components for each circuit. If there are separate receiving and transmitting transducers, make sure you use them the right way round (not that I have ever found an error here to have much effect on performance!). If the receiving transducer has one of its terminals connected to its metal case, make sure that this is the terminal which connects to the negative supply rail so

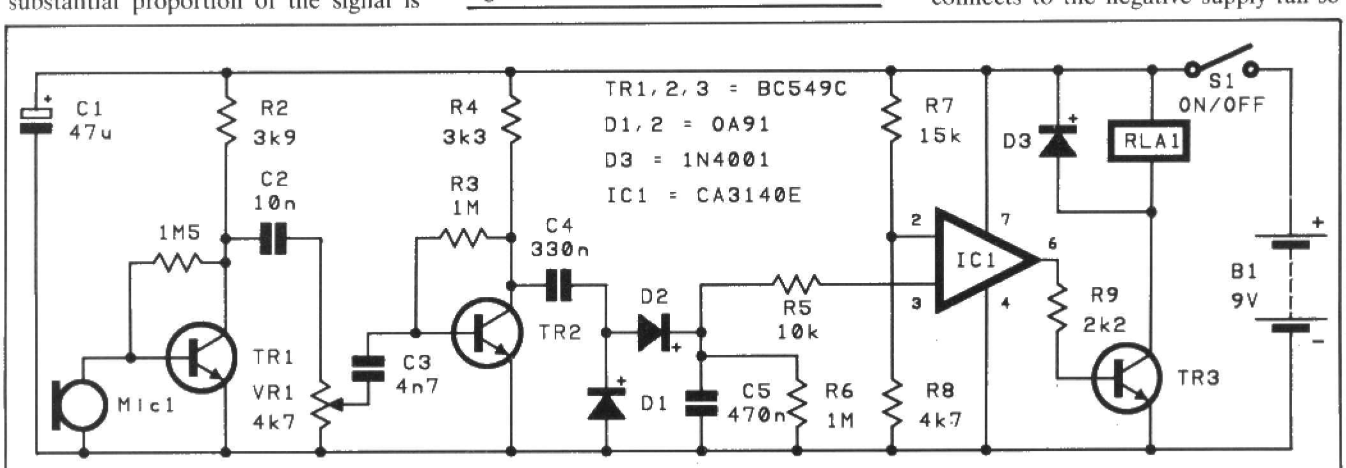


Fig.5. *The ultrasonic receiver circuit*

that stray pick up in the input wiring is minimised.

Direct pick up of the transmitted signal is nothing like as troublesome as you might expect. This is due to the highly directional nature of ultrasonic sound waves. Reasonably low direct pick up should be obtained provided the two transducers are not mounted very close together. I found that about 75 to 100 millimetres of separation was quite adequate.

VR2 must be adjusted for good efficiency from the system, and measuring the voltage across C5 is a simple but effective way of obtaining a relative indication of the received signal strength. It is then just a matter of adjusting VR2 for maximum voltage, with VR1 being adjusted to keep voltage readings within reasonable bounds (between about 0.5 and 3 volts should be satisfactory).

Obviously the unit must be sited where it is "looking" into a reasonably open area. With the unit mounted a metre or more from the floor and aimed into a totally vacant area, an average size person can normally be detected at a range of a few metres. With a lot of objects giving reflections under quiescent conditions the unit will probably give much less impressive results. For optimum results VR1 should be advanced as far as possible without the unit being activated. Keep well out of the unit's field of "view" when making this adjustment. The angle of "view" obtained with most ultrasonic transducers is quite narrow, and the unit will almost certainly only offer good range almost directly in front of the transducers.

Anyone wishing to experiment with more sophisticated ultrasonic detectors should consult the issues of PE dated February and March 1987. These dealt with circuits that provide ranging and not just presence detection, using a technique which is basically the same as a bat's "radar".

HOT STUFF

Most up-market presence detectors seem to rely on microwave radar devices or passive infra-red detectors. The former offer an interesting line of experiment, but the transmitter/receiver units they are based on are quite expensive (about £40.00) and to be strictly within the UK regulations the system as a whole must have type approval. The system of approval seems to operate in a similar manner to the old metal detector licenses, but as yet I do not have definitive information on what is involved in obtaining type approval. This is a subject to which we might return at a latter date.

Passive infra-red detectors are much cheaper, and are free of any licensing requirements. They are very interesting devices for experimentation purposes, as well as having many practical applications. They are something that no self-respecting electronics experimenter can afford to leave untried!

These devices are made from a slice of a special ceramic material which has electrodes on opposite faces. The effect they rely on is reminiscent of the piezo electric effect used for crystal microphones etc, but the charge across the electrodes is produced by heat rather than twisting of the material. The slice of ceramic material is made very thin in order to give a reasonably fast response time, but we are still only talking in terms of an upper −6dB point at something in the region of 3Hz! The output impedance is very high, and practical devices normally come complete with a built-in source follower buffer stage. The input bias resistor of this amplifier leaks away the charges generated on the sensing element, and this limits the low frequency response (typically to a −6dB point at about 0.2Hz). Due to their very restricted bandwidth these "pyro" sensors can not reliably detect a static infra-red source, and must be used in some form of movement detector.

someone to jump over or duck under the beam. A curtain lens gives excellent reliability with full floor to ceiling coverage (except quite close to the lens of course).

Quite simple electronics are involved, with the low level output from the pyro sensor being fed to a two stage high gain amplifier. Lowpass filtering minimises problems with noise, but it is still noise from the pyro sensor that imposes the upper limit on performance. Some sensors use twin elements connected in anti-phase so that any background noise they pick up tends to be cancelled out. In contrast, as the infra-red signal is swept across the sensing elements it gives a signal of first one polarity and then the other, resulting in a doubling of the peak to peak output voltage.

The output from the amplifier is fed to a window discriminator. Normally the output voltage of the amplifier will stay within the 'window', but when triggered it will stray outside the normal limits. This sends the output of the window discriminator high, and activates the relay via a simple driver stage.

A practical circuit using a pyro sensor is provided in Fig.7. R1 is the load

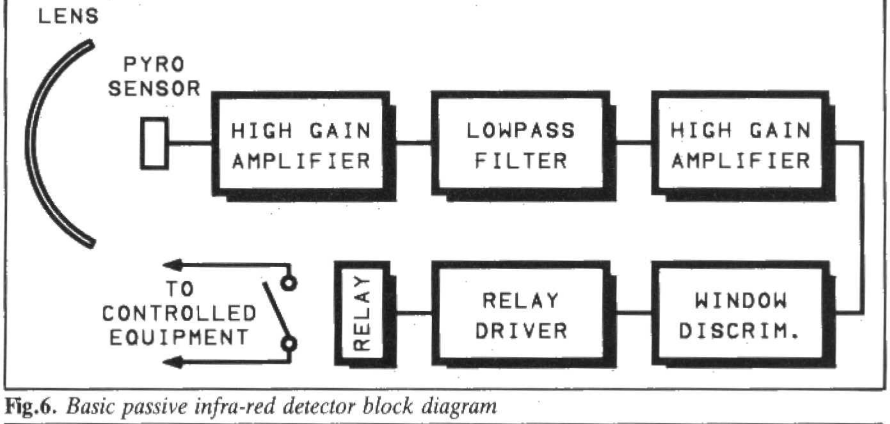


Fig.6. *Basic passive infra-red detector block diagram*

The usual arrangement is something along the lines shown in Fig.6. The pyro sensor is used in conjunction with some form of lens, which is normally a fresnel type that divides the monitored area into alternate zones of high sensitivity and "blind" spots. Anyone moving from one zone to another produces a varying output from the sensor and activates the unit. Alternatively, a convex lens can be used to give a narrow corridor of high sensitivity.

A third, and very effective type of lens, is the so-called "curtain" type. This is a form of fresnel lens, but it gives only two closely spaced zones of high sensitivity. It gives an effect like an invisible curtain which can be used to divide a room in two. Anyone crossing through the "curtain" triggers the unit. It differs from the response obtained using a convex lens in that it has a narrow horizontal coverage but a large vertical angle of "view". With beam type sensors you have to use several vertically stacked beams in order to make it impossible for

resistor for the source follower in pyro sensor IC1. IC2 and IC3 form what is virtually a high gain, two stage, audio amplifier circuit, but the capacitor values have been made high in value so as to give a suitably extended low frequency response. C5 provides the lowpass filtering. IC4 is the window discriminator, and VR1 is used to "open" and "close" the window. A narrow window gives high sensitivity, a wider window gives lower sensitivity. However, making the window too narrow will make the unit vulnerable to false alarms. VR1 must provide the narrowest window that provides reliable results, which involves a certain amount of trial and error.

DOUBLE VISION

The SBA02 pyro sensor is contained in a three lead TO-99 style case. It is a twin element type, and in normal use is mounted so that the rectangular window is horizontal. I would strongly recommend the use of lenses specially designed

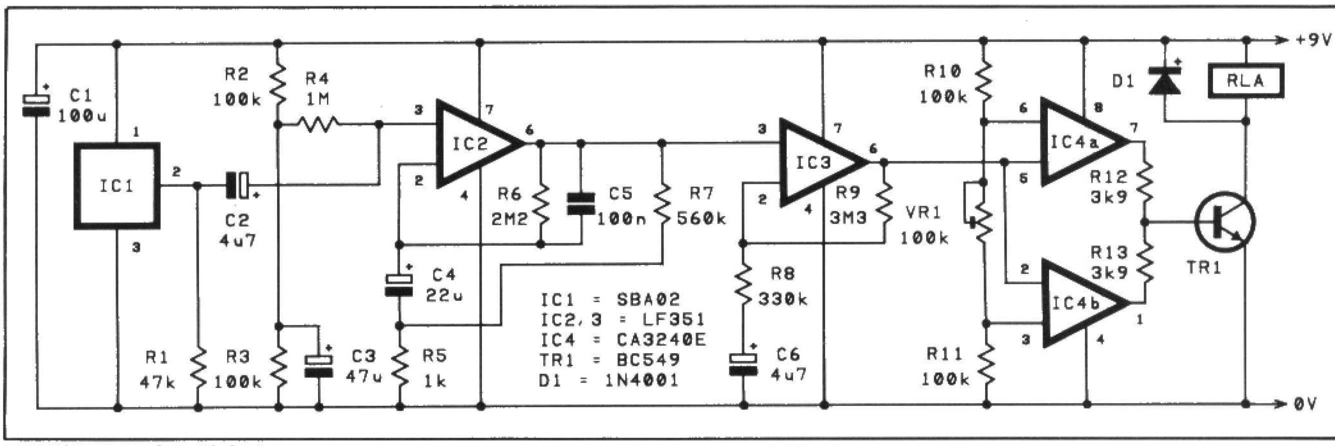


Fig.7. *Passive infra-red detector unit*

for this type of application as normal lenses seem to be completely useless. We are dealing with very long wavelengths of about 7 to 12 microns, and at these wavelengths ordinary lenses either seem to be opaque or simply let the infra-red pass through without any significant refraction! Two inexpensive fresnel lenses for use with pyro sensors are available, and these are the CE24 and CE26. The former gives a wide angle of coverage while the latter is a curtain type lens. A range of up to about 10 metres can be achieved with the CE24, but the CE26 should give at least three times the range. It has 100 degree field of coverage, but horizontally its two lobes of sensitivity are just 2 degrees wide and separated by two degrees. In an application where this type of response is appropriate it offers an amazing level of performance.

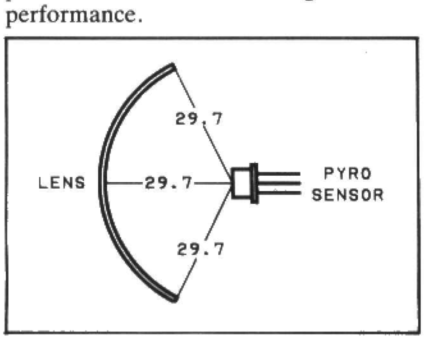


Fig.8. *Required lens curvature*

These lenses are supplied as what are virtually flat pieces of plastic, and their mountings provide them with the correct curvature (see Fig.8). This requires a little ingenuity, but is not too difficult. A slight lack of accuracy only seems to marginally reduce performance. Ideally the lens mounting should be airtight. Passive infra-red sensors are reasonably free from problems with spurious triggering, but turbulence close to the pyro sensor can cause difficulties. An important point to note is that the CE24 is used horizontally, but the CE26 must be mounted vertically (or "landscape" and "portrait" formats as photographers would have it).

Passive infra-red detectors offer excellent performance, but remember that, unlike the other detectors described in this article, they are movement detectors. They are only sensitive to someone moving across their field of "view". Also, they are heat detectors, and will not detect an object that does not radiate a reasonable amount of heat. This is often an advantage, as it makes them pretty well moth-proof, etc.

The SBA02 pyro sensor, CE24 and CE26 lenses, plus white window material are available from Chartland Electronics Ltd., Twinoaks, Cobham, Surrey, KT11 2QW (Tel. 037284 2553). PE

CLOSE ENCOUNTERS

An acquaintance of mine has a burglar alarm that is activated by magnetic switches at strategic points and for a long time it gave him much peace of mind.

Until, that is, he was adopted by a cat. Being a kind hearted fellow he hated keeping Felix out in the cold while he was at work. Instead, he installed a cat door. It has a magnetically operated catch that only responds to a suitable collar around the cat's neck. It's meant to prevent hordes of marauding cats from around the neighbourhood enjoying his hospitality.

Well, this cat, inquisitive as the rest of its race, delighted in investigating around the house, particularly the human entry points it was also accustomed to use. The alarm contact on one of these doors was less precisely adjusted than it should have been, and yes, you've probably guessed it, moggy's magnet collar kept triggering it while Owner was out. It took Owner a long time, though, to realise the cause of the problem!

My window cleaner tells me that he has to be careful when passing parked cars with his metal ladders — it's embarrassing, he says, to explain to irate owners that their car's proximity alarms have not been maliciously set off.

Ed.

A COMPACT A–Z OF ANALOGUE SEMICONDUCTORS

BY CHRIS KELLY

STACK IN THE BOX

Analogue circuits have held the fort against the digital invasion by jumping on the ic bandwagon – from single-function devices, to matched transistor pairs to whole circuits, all on a single chip.

Before the 1960s, analogue techniques were dominant in the world of electronics. Digital methods played a minor role simply because of the complexity and expense of making logic circuits from discrete components; just one logic gate required a handful of transistors, diodes and resistors. Advancing and cheaper integrated circuit technology has created a vast range of applications for digital electronics, now seemingly dominating analogue.

But this increase in digital techniques is not to the exclusion of analogue. Look in any supplier catalogue and you will find that many of the time-honoured analogue circuits and some new ones are now available in ic form. They are cheaper, simpler to include in a design and often more efficient than using discrete components. They have opened up a new world of applications.

This A–Z guide gives a general coverage of the many types of circuits available, the terms and jargon used. It should be useful as a refresher for the experienced or as an overview introduction for the newcomer.

ANALOGUE SWITCH

An electronically controlled switch, based on a semiconductor device such as a fet, which exhibits a low on resistance when the switch is 'closed' and a high off or 'open' resistance. Being a semiconductor device, it exhibits low transient switching compared with the bounce of mechanical switches.

Analogue switches are available in dual-in-line ic packages (see Fig.1), containing a variety of switches. Typical device numbers are:

4051BE & 74HC4051	(1-pole 8-way)
4052BE & 74HC4052	(2-pole 4-way)
4053BE & 74HC4053	(3-pole 2-way)
HI200-5	(dual spst)
HT201-5	(quad spst)

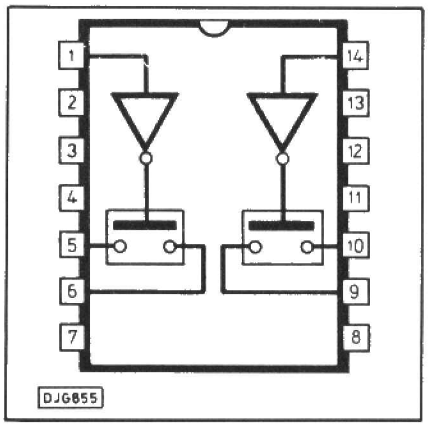


Fig.1. *A dual spst analogue switch*

ANALOGUE-TO-DIGITAL CONVERTER (ADC OR A/D)

A device which outputs a digital code which is proportional to an analogue signal present at its input. For example, a 3-bit converter as shown in Fig.2, will give all 1s (111) when the input is a maximum voltage, all 0s (000) when the input is zero, and a binary mixture of 1s and 0s for voltages between zero and maximum.

There are many types of adc, each requiring a *conversion time* from nanoseconds to microseconds depending on the method of conversion. The *resolution* of a converter is the minimum difference in input voltage which causes a binary change of 1 in the digital output.

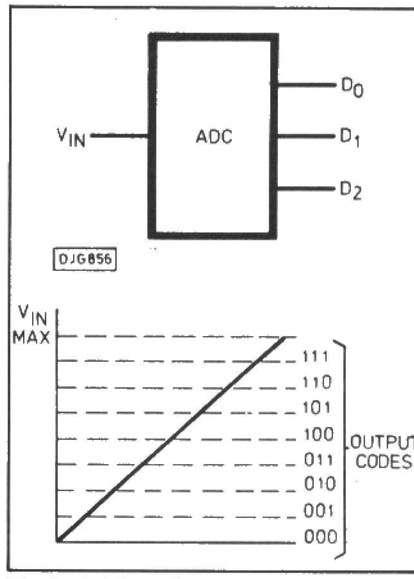


Fig.2. *A 3-bit adc showing output codes*

A more detailed description of adcs will be given in a future A–Z feature on converters. Typical device numbers are:

ADC0804 8-bit A/D
ADC820CCN 8-bit high-speed A/D
ADC0831CCN 8-bit with serial in/out
ZN448E 8-bit tri-state parallel

AUDIO ATTENUATOR

An amplifier with a gain less than one, controlled by an external voltage or resistance (see Fig.3).

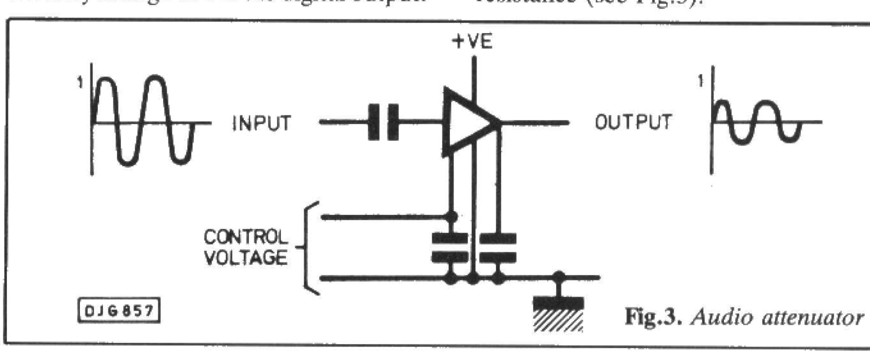


Fig.3. *Audio attenuator*

BI-POLAR DEVICE

Semiconductor device which operates using both types of charge carriers: electrons (negative charge carriers) and holes (positive charge carriers). The junction transistor is a bipolar device, whereas the fet is uni-polar because only one charge carrier flows through the channel.

COMPARATOR

A device for detecting when a varying voltage signal reaches a threshold value. An analogue comparator compares an input voltage against a reference level or against another input, and the output switches state when the input voltage exceeds the other (see Fig.4).

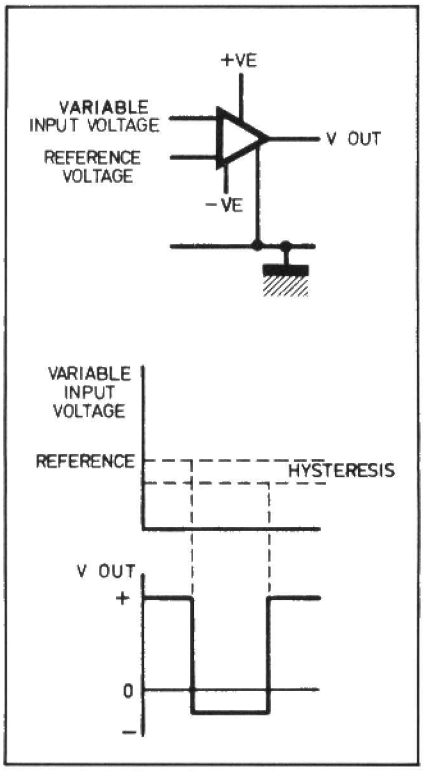


Fig.4. *Typical analogue comparator*

Operational amplifiers can be used as analogue comparators but special purpose comparators are available. These have quicker switching times and low *hysteresis* which is the difference between the switch-on threshold input voltage and the value to which the input voltage must fall below the threshold for the device to switch off.

The 710, a popular high-speed voltage comparator in a 14-pin ic package, can switch in nanoseconds and has a hysteresis of 2mV. The 319 is a dual comparator in one package, requiring a single supply rail.

COMPLEMENTARY TRANSISTORS

These are pairs of transistors, one npn and the other pnp with closely matched performance characteristics. They are used for applications such as push-pull amplifiers (Fig.5) where one transistor amplifies the positive half cycles of the signal waveform and the other amplifies the negative half cycles for greater efficiency.

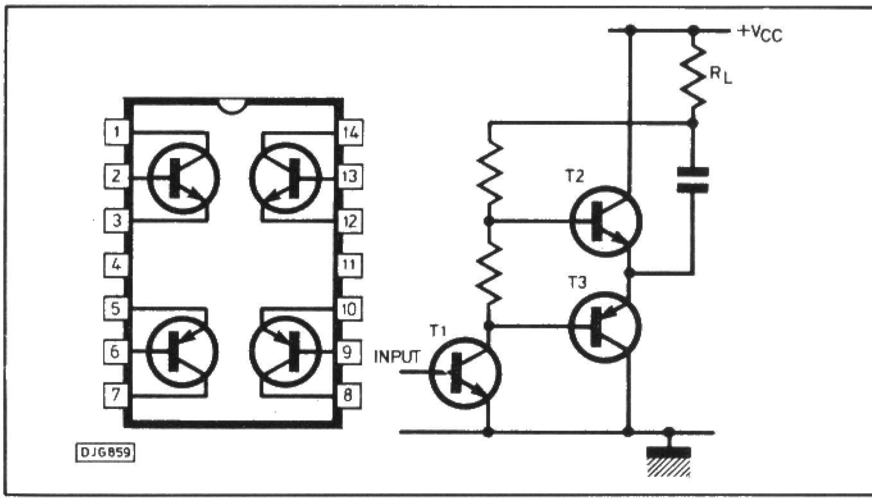


Fig.5. *Complementary transistors and push-pull amplifier*

Complementary transistors are now available as single packages, sometimes containing multiple complementary pairs with some thermal matching which means their performance characteristics change by the same degree as a result of change in temperature.

DARLINGTON DRIVERS

Two transistors connected as a Darlington pair can achieve a much greater current gain than one transistor. They are often used to drive loads such as relay coils (Fig.6) and in series voltage regulars. Quad (four) and octal (eight) Darlington drivers are available in a single ic package, including inbuilt protection diodes.

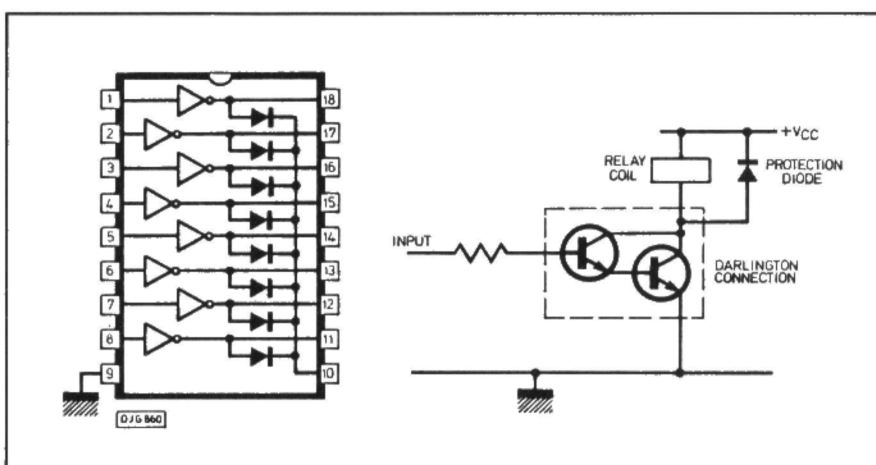


Fig.6. *Darlington drivers*

A protection diode is reverse-biased when the Darlington pair conducts and current passes through the relay coil. Yet when the driver switches off, the diode allows current, caused by back-emf as the magnetic field of the coil collapses, to circulate. Protection diodes speed up the switch-off of the coil and protect the Darlington drivers from back-emf.

DELAY LINE

A means of creating a delay in the transmission of an analogue signal for a fixed time interval. Typical applications are for electronic musical effects such as artificial reverberation and introducing delays into public address systems so that the audio signal reaches each speaker simultaneously.

The bucket brigade delay (bbd) principle (Fig.7) is often used where you can imagine the analogy of buckets being passed along a line of people where the contents of each bucket represents a sample of the analogue waveform.

Very simply, analogue switches are opened and closed alternately so that the charge on a line of capacitors is passed along the line, where each charge is a sample of the analogue input. A two-phase clock controls the opening and closing of alternate switches. The result at the output is a series of delayed, chopped amplitude samples of the input waveform.

The chopping of the waveform introduces many unwanted frequency components which can be removed from the output by filters.

Practical devices include the MN 3044 which is a mos monolithic ic with 512 stages (buckets!) providing delays from

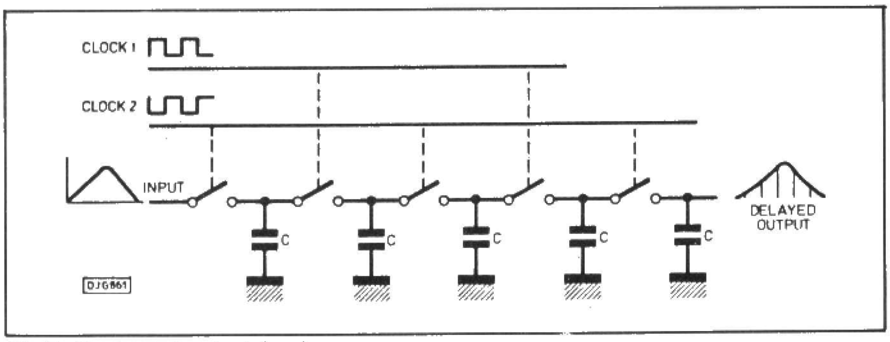


Fig.7. *Bucket brigade delay line*

2.65ms to 25.6ms. The MN 3011 has 3328 stages with six output taps and having a full delay range of 16.64ms to 166.4ms.

There are many short delay lines available, such as the 63 microsecond delay lines for television receivers, which are not suitable for audio use. The reason for this is that delays in the range of several milliseconds are required for the effects to be audible. As each stage of a delay line introduces its own errors, cascading a number of short delay lines would increase the distortion for audio to an unacceptable level.

DIGITAL-TO-ANALOGUE CONVERTER (DAC OR D/A)

A device which converts a digital code into a proportional analogue voltage (Fig.8). For example, a 3-bit converter can generate eight levels of voltage, each level representing one of the binary combinations possible with 3-bits.

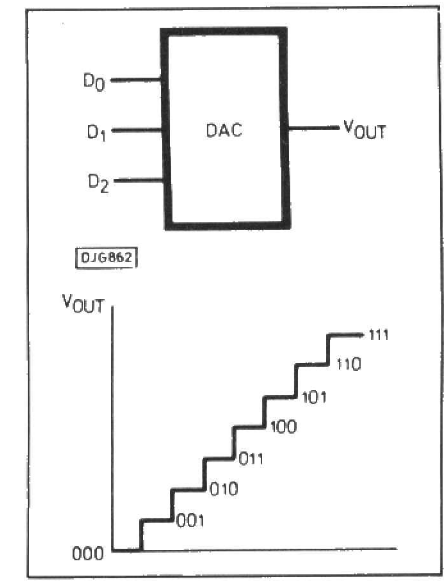


Fig.8. *Digital to analogue converter*

The output voltage is not true analogue but is in discrete steps, called *quantisation levels*, and no voltages can be output between these levels. This is the source of error in dacs, called *quantisation error.*

Dacs are used for waveform generators, industrial control applications and now in compact disc players to reconstruct the analogue music from digital codes. An A–Z feature is planned dealing specifically with dac and adc. Typical device numbers:

DAC0801 8-bit d/a
AD7581 8-bit 8-channel d/a
ZN428 8-bit d/a
DAC703JP 16-bit d/a

FIELD EFFECT TRANSISTOR (FET)

A semiconductor device which can amplify voltage signals or act as a switch. The fet has certain advantages over the bipolar transistor it is not as susceptible to temperature variations, having high input resistance and low noise which makes it suited for the early stages of amplification.

Very simply, the fet operation is as follows: an input voltage signal applied to the gate terminal creates an electrical field which controls the flow of current from an external source in a channel between *drain* and *source* terminals.

There are three main types of fet. The *junction gate* fet (jfet), the *metal-oxide-semiconductor* fet (mosfet or most) and the vmos power fet which has a V-shaped channel for switching high currents (typically 2A) very quickly (tens of nanoseconds).

HYBRID INTEGRATED CIRCUITS

These have a ceramic support often called a substrate, upon which is mounted several other types of circuit such as silicon chips, power transistors and film resistors. The advantage is that one hybrid package can mix component types which would be difficult to manufacture as a *monolithic* ic.

INSTRUMENTATION AMPLIFIER

A high performance operational amplifier having substantially lower drift characteristics than standard operational amplifiers.

MATCHED PAIR

Two transistors manufactured in one piece of semiconductor to exacting tolerances so that their performance characteristics are almost identical. Any change in operating conditions such as temperature or humidity change affects each of the matched pair equally.

MONOLITHIC IC

A complete circuit manufactured on a single piece of silicon. The word monolithic literally means "single stone". The term monolithic can also be used for other devices, eg monolithic ceramic capacitors.

MULTIPLEXER

An analogue multiplexer (Fig.9) contains a number of switches which when selected to "close" one at a time connects the signal path from one input channel to a common output, rather like an electronic version of a multi-way switch. The channel is selected by a code applied to address inputs (A0 and A1 in diagram). Analogue multiplexers are used extensively for data acquisition systems, audio and video switching.

Multiplexers can be built around discrete fets, but are now available as complete ics, such as the LF13508, but are now available as complete ics, such as the LF13508, 8-channel multiplexer or the 16-channel LF13526. Other device numbers:

74153 4-line to 1-line
74151 and 4512 8-line to 1-line
74150 16-line to 1-line

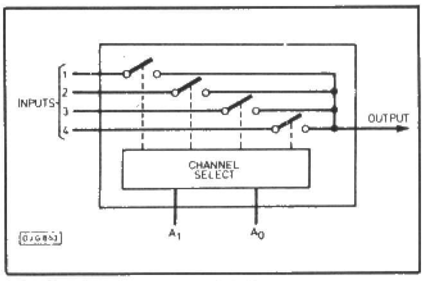


Fig.9. *Analogue multiplexer*

OPERATIONAL AMPLIFIER (OP AMP)

A high gain voltage amplifier which is direct coupled (no capacitors) so it is suitable for amplifying dc or ac signals. Operational amplifiers have *differential* inputs, one inverting (−) and one non-inverting (+) and exhibit very high input impedance and very low output impedance. They are used extensively for industrial instrumentation, small signal processing, general purpose amplifiers and summing amplifiers.

Bipolar operational amplifiers have low output impedance and high slew rates (rapid change of output measured in volts per microsecond). Cmos operational amplifiers exhibit very high input impedance and have low power consumption but with lower slew rates.

An A–Z feature is planned dealing exclusively with operational amplifiers and their applications.

Typical device numbers:

Bipolar: LM301A 709
LM308 741
LM324 NE531

cmos/fet: LF441, 442, 443
LF351, 353, 347
CA3130

RMS TO DC CONVERTER

A device which will output a direct current which represents the true rms value of the input signal. The rms value is different for different types of waveforms and ic devices are available which compute for sinewaves, squarewaves or any complex waveform containing ac into the mega-hertz region or both dc and ac components.

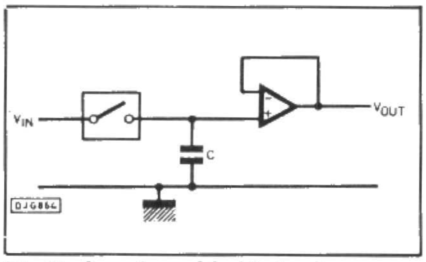


Fig.10. *Sample and hold circuit*

SAMPLE AND HOLD (S/H)

For many data acquisition applications, a rapidly changing analogue voltage must be frozen at a particular instant in order that an analogue-to-digital conversion can take place accurately.

The s/h circuitry (Fig.10) includes a fet switch which when closed (sampling) allows the voltage on capacitor C to change with the varying input voltage, Vin. When the switch is opened (hold state), the voltage across C is held constant which appears as Vout through the buffer. The buffer is an operational amplifier with high input impedance to prevent the capacitor discharging.

Acquisition time is the time required to change from one holding voltage to new voltage level with a step of 10V.

Droop rate is a measure of the holding voltage fall-off in millivolts per millisecond, and depends on the quality of the capacitor and the high input impedance of the buffer.

TRANSISTOR ARRAY

A number of transistors in one ic package (Fig.11). Used in applications where space saving or close thermal matching (ie changes in performance due to temperature changes) are important.

A typical device is the CA 3046 which consists of five npn transistors.

VOLTAGE-CONTROLLED OSCILLATOR

A device which converts a variable analogue input voltage to an output voltage whose frequency is directly proportional to the input voltage. Ics are available which output pulses at a frequency proportional to the input voltage and some devices can work in reverse, giving a voltage proportional to the frequency of the input. One frequently used device is the cmos 4046. PE

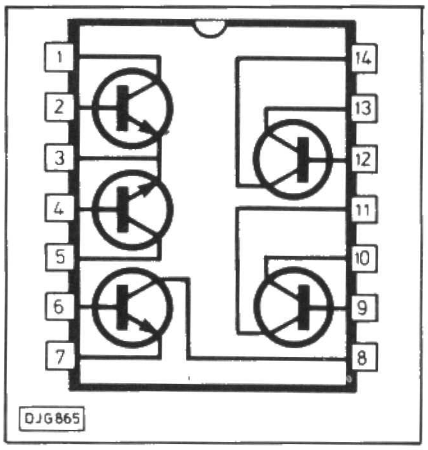


Fig.11. *Transistor array*

PE BOOK SERVICE

If your looking for more information about analogue circuits see the PE Armchair Book Shop on page 54.

READERS' LETTERS

STARRING PE

Dear Ed,

Over the last few years my electronic dabbling has been neglected, but now having retired, I find there is time to catch up on what I have been missing.

The first thing I did was purchase PE once again and I noticed that you have added 'Spacewatch' to the articles. I also see that *Astronomy Now* is published by the same company as PE. One of my main hobbies over the years has been telescope making, so it occurred to me that there is an opportunity to make a plea for projects on astronomical electronics. How about electronic control of telescopic movements using stepper motors linked to a computer? Electronics could also be used to lock on to a guide star when using an astro camera. There are many other similar areas in which one could use electronics if only someone would produce the projects in print.

There are a lot of amateur astronomers in this country and PE could be a sister magazine to *Astronomy Now* on a practical basis. So please may we have an astro electronics section in PE?

W.C. Trice, Peacehaven.

I share your views and already have some astronomy-electronics articles coming up relating to infrared and ccd (charge coupled device) photography. These are not constructional articles but features written by researchers at Herstmonceaux and Edinburgh Observatories.

I should very much like to be offered electronic projects relating to astronomy, and would also welcome further suggestions for them.

One idea that Dr John Mason of AN has already discussed with me is the possibility of an astronomical alarm clock. It seems that astronomers keep getting up in the middle of the night to see if the sky is clear enough for observations. All too often they find they've risen unnecessarily as the skies are clouded over. We have chatted about designing some sort of clear sky sensor that will only set off the alarm when really justified. It's not as easy as it might seem and as yet we've come to no practical low-cost conclusion (unhappily, the use of ccd sensors is too expensive to have widespread appeal). Does anyone have any ideas that will allow Dr John to maximise his snore-to-view ratio?

Ed.

GENERATING POWER

Dear Ed,

I have read with interest your poignant 'Weather Beaten' Editorial of Jan 88. Please accept my commiserations for the 'technological indignity' you experienced during the Great Gale of '87. We experience frequent power failures in Nairobi, although more usually as a result of human factors than acts of God ...

Anyway, at the moment I am concerned with alternative energy systems for low cost house designs and wonder if you can offer advice regarding small-scale petrol or diesel driven generators manufactured in the UK which might be suitable for recharging 12V car batteries. I have in mind an idea for battery powered fluorescent lighting systems using a generator run on a village cooperative basis. Regrettably solar power panels are still too expensive in Kenya to consider them as the supply source.

Surprisingly, I haven't been able to obtain information in Nairobi and it seems that where generators are used they are for direct lighting systems rather than for battery charging.

Robin Short, Nairobi, Kenya.

My phone directory shows five companies who are practically my neighbours:

Aggreko Generators Ltd, 89 Beddington Lane, Croydon, Surrey. 01-689 5511.

John S Allen & Son Ltd, 4 Downsview Road, London SE19. 01-771 3323.

Electro Dynamic Construction Co Ltd, Station Approach, St Mary Cray, Orpington, Kent. 0689 32051.

Power Mart, 413–415 Ilford Lane, Ilford, Essex. 01-514 0700.

Stephill Generators Ltd, Unit 5, Samuel Jones Ind Est, London SE15. 01-708 0083.

Ships chandlers might also be able to help since many boats require 12V or 24V power sources.

I am a bit puzzled though — if the generators you know of produce mains voltages, why can't you use a normal battery charger? If they are 24V ac generators, using a heavy-current rectifier feeding into two 12V batteries coupled in series should also be practical. **Ed.**

PICK AND CHOOSE

Dear Mr Becker,

This is to thank you for your letter telling me I had won a subscription to PE in the satellite tv competition.

To be truthful, I am much more pleased to have the prize I won rather than the satellite tv set-up. No doubt it is my age, but I find fewer and fewer tv programmes with any real merit or veracity. Since we are constantly being told that we have the best tv programmes in the world can, I ask, a tele-dish bring us anything more? The real problem with tv is that, unlike steam-radio, it takes total attention for, more often than not, trivia.

I am struggling to find time, as it is, to complete a small circuit that will interface my Apricot portable, with its rgb output, to an ordinary tv set. I suspect the result may be an inverted signal (which won't matter much) and only a 40 column screen (which may prove tedious) but it is a lot cheaper than an rgb monitor. After that I hanker after building my own weather satellite receiver to input to the computer and (hopefully by then) a decent monitor. But I fear I shall go to my grave clutching yet another (to me) incomprehensible circuit diagram.

Thanks for the competition; it was interesting and fun.

Sylvia M. Pick, Ledbury.

Apart from nature, technology and current affairs programmes I regret that tv does not hold much attraction for me either. The only benefit I usually find in other programmes is that they enable me to doze off prior to getting back to dabbling with the soldering iron.

I too would like to get into weather satellite reception and have been having tentative chats with my counterpart on Astronomy Now. Perhaps I'll soon be able to offer a comprehensible circuit.

But I hope that neither of us, to rephrase William S, will shuffle off this mortal coil or abjure our rough magic 'till all's refined to potent art. **Ed.**

TEACHER TALKBACK

Dear Tim Pike,

I am a fourth year pupil studying GCSE technology and am making the Teacher Talkback intercom from PE Jan and Feb 88. Where can I obtain the 80 ohm speakers you specify?

Matthew Jowitt, Calver.

Dear Matthew,

80 ohm speakers may be a little difficult to get hold of sometimes but there is no reason why you should not use another relatively high impedance type instead. Some companies work to 64 ohms, and others to 75 ohms. Either of these would be fine. I have looked in some catalogues and offer some possible sources to you —

Cirkit, tel 0992 445736. 64 ohms, code 43-02564, 80 ohms, code 43-02580.

Greenweld, tel 0703 772501. 64 ohms, code A302.

Maplin, tel 0702 554161. 64 ohms, code WF57M.

Rapid, tel 0206 272730. 64 ohms, code 35-0135.

Best wishes with your project.

Tim Pike, Orpington.

THERMAL EXAM

Dear Mr Becker,

For my forthcoming Craft, Design and Technology (CDT) exam I have to produce a paper in which I report on my investigations into electronic methods of measuring and displaying temperature. Have you published any circuits recently which might help me?

Clive White, Portsmouth.

Part two of the Prof's article on Sensors in PE May 87 specifically covers thermal transducers. Also, my Weather Centre project shows a simple temperature detector in part one, March 88. Coming up shortly is another method as part of a barometric pressure sensing project. Stay hotly with PE!

Ed.

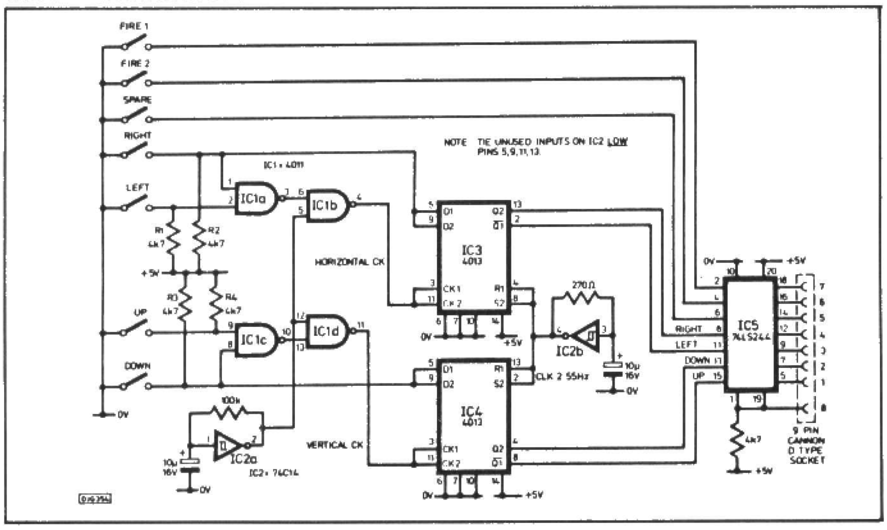
WEATHER VANES

In the Weather Centre project of Mar–May 88 I commented that weather vanes seemed to be hard to locate. I am pleased to tell you that I have recently found a company who make them. Metalarts of Devon were exhibiting at the Penshurst craft fair in May and have a good range available, from the conventional to the more exotic.

Metalarts of Devon are at the Petrockstow Forge, Petrockstow, Okehampton, Devon. **Ed.**

"INGENUITY UNLIMITED"

AN AMSTRAD MOUSE SIMULATOR



THE joystick port on the Amstrad CPC computers is scanned as part of the keyboard system at a default speed of 50 times every second. Anyone who has tried to use the joystick for accurate control of the screen cursor position will have found it difficult. This is due to the rate at which the computer scans the joy-stick port, requiring only a small movement on the joystick to produce a large movement of the screen position. The following circuit was designed to get around this problem by converting the joystick switch positions into a stream of pulses on the joystick lines, similar to those generated by moving a mouse.

The circuit consists of only five dil ic's these go to make up the input gating from the direction switched, two astable clocks, direction latches and a tri-state buffer to drive the joystick port on the computer. The Schmitt invertor gate IC2a and it's associated components R5 and C1 form the first astable clock which is fed to one of the inputs on gates IC1b and IC1d whose outputs generate the vertical and horizontal clocks and which are used to clock the position latches IC3 and IC4. The outputs of IC1b and IC1d are normally held high by the low outputs from IC1a and IC1c, only when one of the four position switches are pressed does the relevant clock get gated through to the latch. This signal now clocks the selected position through to the Q2 and NOT-Q1 outputs. This will appear at the joystick port each time the port is scanned. However the second astable clock made from IC2b and R6,C2 clocks the set and reset inputs on the position latches every 18ms, changing the state of the latch outputs to a high state. As the computer only scans the port for a low condition to signify joystick movement it no longer sees the port as active and will cease to increment the screen position.

If the position switches are kept depressed then the position clock will remain active and will re-clock the position into the latch, appearing once again on the joystick port before being cleared by the second astable clock. The overall effect of this action is to only allow the position switches to be available for reading by the port for a short period of time before being cleared, hence only updating the screen position by small amounts each time. The circuit uses cmos ic's to keep power consumption to a minimum the four pullup resistors R1 to R4 are to prevent the inputs of IC1 from floating when no position buttons are pressed.

A small plastic box used to house the circuit. Seven normally open push-buttons were mounted on the lid, three in a row at the top providing fire1 fire2 and spare fire button. The four position switches were arranged below, similar to the cursor key layout. Wires were taken down from these switches to the main circuit board mounted in the base of the box. Two leads were brought out of the rear of the box, one having a 9 pin socket to connect into the joystick port, the other carried the power to the circuit board. The +5v required may be picked up from the expansion connector pin 27. The usual static precautions should be observed when handling the ic's and the use of dil sockets recommended. When the unit is completed and plugged into the computer, enter the following program:

```
10 cls:mode1
20 locate 20,12:print joy(0)
30 if joy(0)<0 then 20 else 40
```

The following numbers should be displayed on depressing a key on the unit: TOP LEFT=32TOP CENTER=64TOP RIGHT=16 UP=1 DOWN=2 LEFT=4 RIGHT=8. If the right numbers appear, clear oput the program and enter the next program. This allows simple line drawings to be created on the screen. The top right key cancels the line, top centre allows cursor movement without drawing, pressing it again returns you back to drawing mode, top left makes the line permanent.

R. Hewertson, Leigh

Main program for the Amstrad mouse simulator

```
10 CLS:INPUT"sensitivity=";s
20 MODE 1:INK 3,24
30 x=320:y=200:h=320:v=200:lin=1:GOSUB 140
40 WHILE-1
50 IF INKEY(72)=0 THEN GOSUB 190:v=v+s:GOSUB 190
60 IF INKEY(73)=0 THEN GOSUB 190:v=v-s:GOSUB 190
70 IF INKEY(75)=0 THEN GOSUB 190:h=h+s:GOSUB 190
80 IF INKEY(74)=0 THEN GOSUB 190:h=h-s:GOSUB 190
90 IF INKEY(77)=0 AND LIN=1 THEN GOSUB 240
100 IF INKEY(76)=0 AND LIN=1 THEN GOSUB 270
110 IF INKEY(78)=0 AND LIN=0 THEN GOSUB 270
120 IF INKEY(79)=0 THEN GOSUB 310
130 WEND
140 PRINT CHR$(23);CHR$(1);
150 LOCATE 1,1:PRINT "x=";h;" y=";v;"sensitivity=";s
160 MOVE h,v
170 DRAWR 0,5,2:DRAWR 5,0:DRAWR 0,-5:DRAWR -5,0
180 RETURN
190 IF LIN=0 THEN GOTO 220
200 PRINT CHR$(23);CHR$(1);
210 MOVE x,y:DRAW h,v
220 GOSUB 140
230 RETURN
240 PRINT CHR$(23);CHR$(0);
250 MOVE x,y:DRAW h,v,1:x=h:y=v
260 RETURN
270 GOSUB 190
280 IF LIN=1 THEN LIN=0 ELSE LIN=1:x=h:y=v
290 GOSUB 190
300 RETURN
310 PRINT CHR$(23);CHR$(0);
320 MOVE h,v:DRAW x,y,0:x=h:y=v
330 RETURN
```

Conference Lamp Controller

THE circuit shown in Fig.1. was used at a conference to enable the chairman to remotely indicate to the speaker: continue talking (green), one minute left (yellow), and stop talking (red). Readily available 3-core mains cable was used instead of the 4-core that would normally be needed.

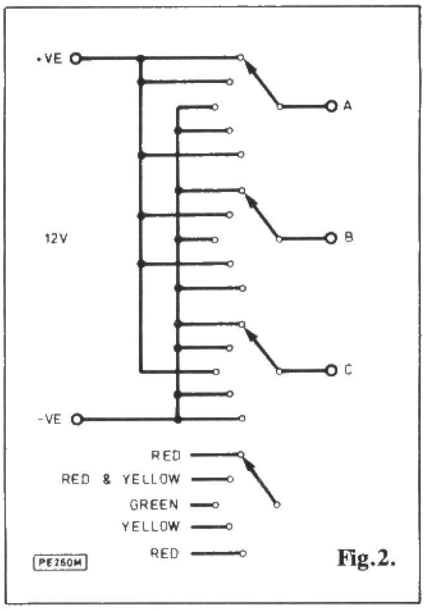


Fig.2.

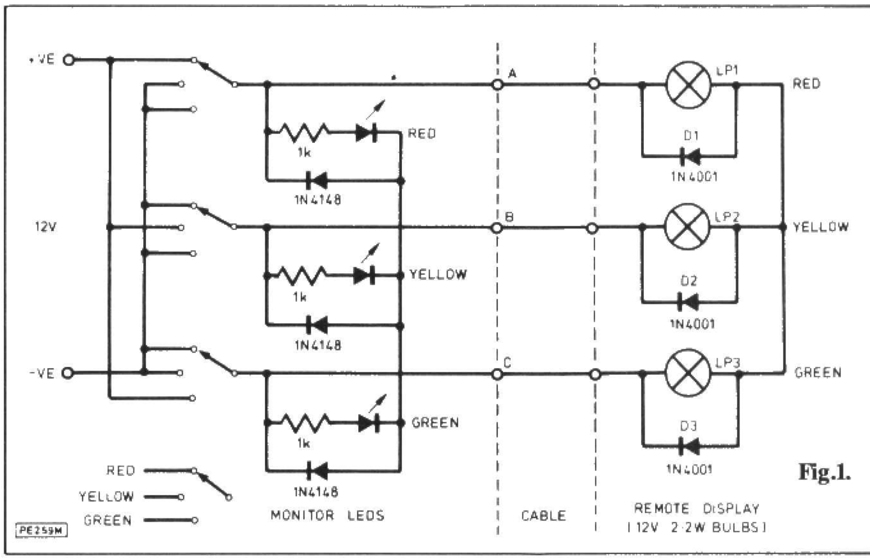


Fig.1.

Each lamp in the remote display unit has a diode across it which is reverse biased when that lamp is on. For example, if the red lamp is on, line A is connected to the positive supply, and lines B and C are connected to the negative supply by the switch. This forward biases D2 and D3, and reverse biases D1, so turning LP1 on, and LP2 and LP3 off. A similar arrangement of l.e.d.s. on the control unit monitors the status of the remote display. Since only one diode needs to be forward biased, any two lamps can be on at any one time. Fig.2. shows the switching required for a traffic light sequence.

The principle can be extended to control any number of lamps with the same number of wires, but it should be remembered that at least one lamp must be off, as at least one diode must be forward biased. The diodes should be rated to carry the combined current of the maximum number of lamps on simultaneously.

K. Wevill, Leicester.

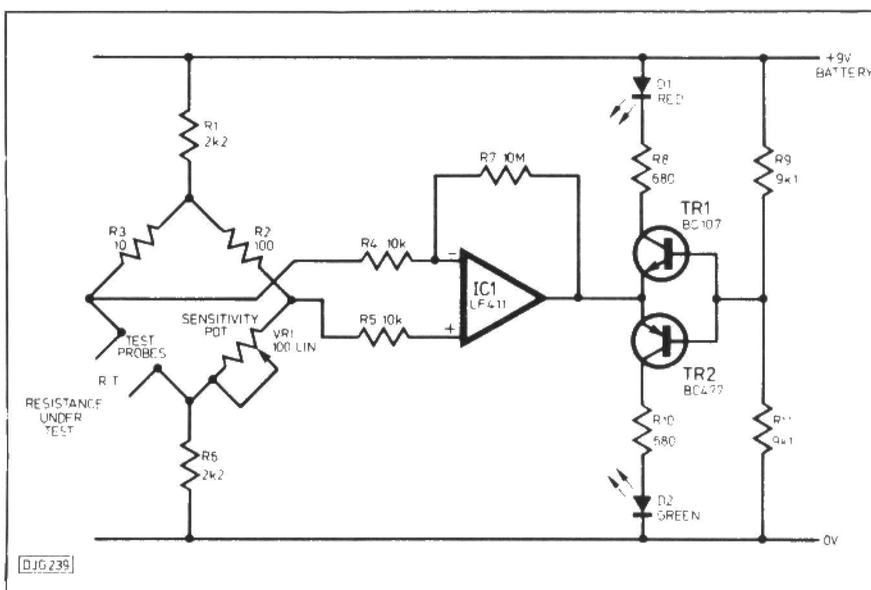
Short Detector

DUE to current needs to have high densities of semiconductors on modern printed circuit boards, accuracy in soldering is of vital importance. As with wrap joints a wrong pin can give devastating results. Looking for bridges and shorts to debug projects can be very frustrating and time consuming. This project was designed to make debugging fast and accurate.

Initially the sensitivity should be set to maximum. The probes from the output marked RT are held against two tracks in the area of the p.c.b. where the short is suspected. This represents the measuring arm and completes the bridge circuit. If the l.e.d. is illuminated the circuit under-test must measure more than 10 Ohms, but if the green l.e.d. is illuminated then the value of the short must be less than 10 Ohms, and the sensitivity control should be adjusted until null is obtained and both l.e.d.s. are extinguished.

Again the bridge is nulled, this procedure is repeated until the sensitivity pot is fully clockwise, indicating zero resistance, therefore the probes are above the short which can now be visually identified and removed.

The measuring component of this circuit is a Wheatstone bridge. The bridge can be balanced for any resistance of 10 Ohms or less, The value of which can be read from a calibrated dial on



VR1. The op-amp IC1 is used to compare the two arms of the bridge. Because of this arrangement, the output level of IC1 can only be one of three values.

When the bridge is balanced the centre point of both arms V1-V2 will have a differential of zero, therefore both points will be at half rail potential. The inputs of IC1 will be the same, thus the output of IC1 will be half the supply.

The bases of TR1 and TR2 are fixed at half supply potential, so when the bridge is balanced, the Vbe of both transistors is zero and is indicated by both l.e.d.s. being extinguished. If the bridge is adjusted and voltage V1 becomes positive with respect to V2 the output from IC1 falls to approximately 1V and TR1 is forward biased so illuminating D1.

If the bridge is adjusted such that V1 becomes negative with respect to V2, i.e. adjustment of VR1, or change in RT value, the output from IC1 goes high, approximately 8V, which reverse biases TR1 and forward biases TR2 to illuminate l.e.d. D2. Resistors R8, R10 are used to limit l.e.d. currents.

D.R. Fowness. Wolverhampton

CD SIGNAL PROCESSING

PART TWO BY VIVIAN CAPEL

THE WISDOM OF REED AND SOLOMON

The binary wordplay needed to squeeze sixty minutes of music onto a three inch disc includes symbolising, interleaving of audio sample frames, three-zero humps, discardable merging bits, delay lines, triple parity checks and double decoding. They say it's great for Heavy Metal...

A lot has been written as to how cd signals are recorded, but some of that published elsewhere has been vague and often inaccurate. In our last article we saw how the player tracks the disc and produces a data stream; now we shall see how the signal is processed, how a quart is compressed into a pint pot, and what happens when dirt or disc imperfections cause signal errors. We hope also to clear up a few misconceptions along the way.

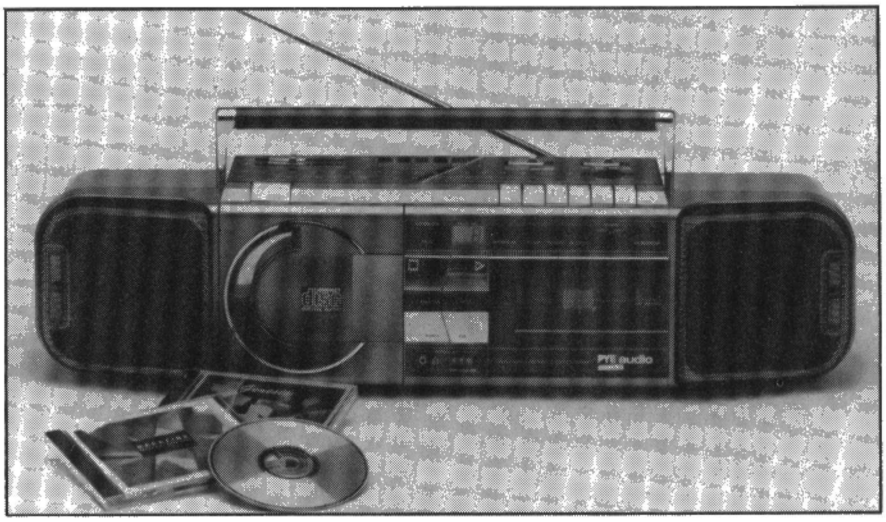
Many readers will be familiar with the principles of digital recording, but for those that aren't we will start with the basics. When a signal in a recording medium, whether an electric voltage or current, magnetic field, or record groove, varies in proportion to the sound pressure wave that caused it, it is termed an *analogue* signal. It is analogous to the original sound.

Now it is not easy to get the signal to correspond exactly. The system may discriminate in favour of, or against certain frequencies, components can resonate producing frequency peaks, spurious harmonics can be added, and so can noise, frequencies can interact generating sum-and-difference products that were not in the original. Any or all of these can occur during recording and again at playback. The end result is *distortion*.

DIGITAL RECORDING

An alternative to attempting to accurately record the actual wave is to measure it, record the measurements, then reconstitute the wave from those measurements. It is obvious that once the measurements have been taken nothing can happen to degrade the signal. Noise and distortion can have no effect as long as the reproducer can recognise the numbers. The only problem that can arise is if some of the measurements are lost.

Distortion could arise if the original measurements were inaccurate or they were inadequate to truly represent the analogue signal. There must therefore be a sufficient number of readings or samples so that the waveform can be properly defined. According to the



Photograph of the TR8848 cd radio cassette recorder by courtesy of Pye

Nyquist Theory, the sampling rate must be at least twice that of the highest frequency to be represented. In the case of the compact disc, the sampling rate is 44.1kHz, which is sufficient to describe a sine wave of 20kHz, the highest audio frequency recorded. The top frequency is bound to be a sine wave because if it was not, the presence of still higher harmonics would be indicated.

Should frequencies be present that are higher than half the sampling rate, the samples appear to the decoder to be values of a much lower frequency, (see Fig.1). This effect is known as *aliasing*. To prevent it, all frequencies above the required range must be severely curtailed. This is done by means of a steep

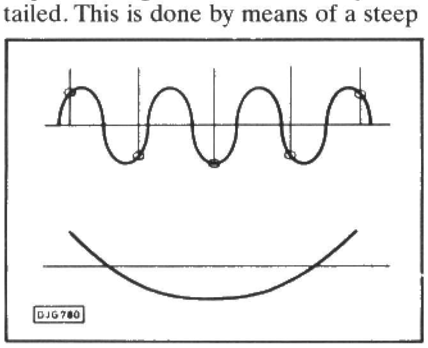


Fig.1. *Aliasing error. When the sampling rate is lower than the highest frequency, spurious low frequencies are produced*

top-cut filter. Having the sampling rate slightly higher than twice the upper frequency limit, besides giving a safety margin, also allows for the filter roll-off.

QUANTISATION

Each sample is represented by a whole number, so the larger the number of measurable levels the more accurate the sample. For example, if temperature is to be measured in whole degrees, the Fahrenheit scale having 180° between freezing and boiling points will give a more accurate result than Celsius which has only 100°. The error caused by a value falling between two levels is termed *quantisation distortion*. The percentage of error caused say by 2.5 being measured as 2, is far greater than 200.5 being rounded off to 200. It thus follows that the effect of quantisation error is much greater at low signal levels. Decaying sounds die away in a series of steps rather than smoothly, producing what can best be described as a 'crumbling' effect.

One way of overcoming this is to space the levels closer together at the low end, a method known as *non-linear quantisation*. With the compact disc 65,535 levels plus 0 are measured, giving 65,536 possible numbers. This is sufficiently high to give very low quantisation

distortion even at low levels, so non-linear quantisation is not necessary.

BINARY CODE

If the sample was recorded as a decimal number, ten different states would be required to represent each digit. This would produce the same problems as an analogue signal, with slight errors producing totally different numbers, especially if these occurred in the left-hand digits. With the binary code, only two states are required to represent 0 and 1, so a series of pulses and gaps can be used. The method is thus termed pulse-code modulation, and is far less likely to result in ambiguity than the use of a decimal number.

While many readers will be familiar with the binary code we will ask them to bear with us for a while for the sake of those who are not. In the binary code, each 1 starting from the right indicates a power of 2 starting with 2^0 which is 1, followed by 2^1 which is 2, then 2^2 which is 4, 2^3 which is 8, and so on. The appearance of a 0 in any position indicates the absence of that power from the complete number. Any number up to 65,535 can be represented by 16 binary digits which is therefore the number of digits or bits used for the compact disc.

For comparison, 15 digits can represent up to 32,767 decimal, 14 digits, up to 16,383, and 13 digits up to 8,191. So the extra few bits mean a lot! Actually, 16 bits is somewhat a case of overkill as the excellent quality achieved with the BBC fm stereo broadcasts is obtained after transmission along studio link lines at 13 bits. However, the excess is undoubtedly to wisely achieve a higher-than-necessary standard from the beginning, and so avoid the need for upgrading later when advances in associated equipment could render a lesser specification obsolete.

FRAME FORMAT

As we have seen, the 65,535 possible signal levels are represented by a 16 digit binary number which is called a **word**. The rh and lh stereo channels are recorded consecutively and so consist of alternate words. This is possible because the data is recorded much faster than it is sampled. Samples are taken at the rate of 44,100 per second from each channel which is 88,200 samples per second. If these were recorded as 16-digit words per sample, this would be 1,411,200 digits or bits per second. The recording frequency is 4,321,800 bits per second, so both channels as well as other data can be recorded consecutively without running out of time. In the reproducer, the samples are stored in a memory as they come off the disc and are then clocked out at the required rate.

Actually, the samples are not recorded as straight 16-bit words. The units need to be shorter because each one is nearly doubled in length later, for a reason we shall see. This would produce unwieldly units which the digital circuits would find difficult to handle. So each word is split into two 8-bit sections called *symbols*.

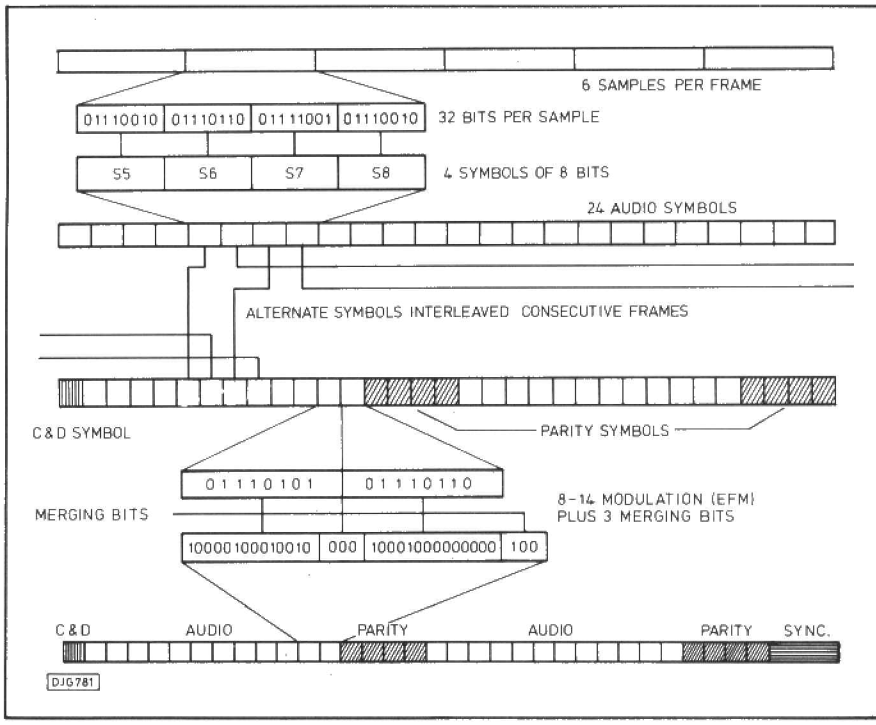


Fig.2. *A complete frame showing composition and successive processing*

The two stereo channels are sampled simultaneously so they constitute a single sampling of the sound field at any instant. Hence both are referred to as a single *sample* in compact disc terminology.

There is a set sequence of audio symbols, parity symbols, control and display symbols, and synchronising bits. A complete sequence is known as a *frame*, all frames having the same sequence. (Fig.2.)

The actual sequence is: first, one *control and display* symbol, which gives data as to title and composer, timing and track number and any other required data. This information can then be displayed on a read-out panel in the player, and the player's computer control can search for a particular track number when so instructed. Finding a track is thus much easier than the hazardous pickup setting down procedure which has to be followed with the standard lp record. Although only one 8-bit symbol is allocated per frame, there are 7,350 frames per second, thus giving 58,800 data bits per second which is ample to record the required control and display information.

Second in the frame come twelve audio symbols which represent six 16-bit words or three complete stereo samples. Next, there are four parity symbols whose function we shall discuss later. These are followed by another twelve audio symbols giving a further three audio samples, after which are another four parity symbols. Finally, there are 27 bits of synchronising data which the decoding circuits recognise, and so can tell where one frame ends and the next one starts. As these come between each frame they can be considered either as ending a frame or starting the next one.

A complete frame thus consists of 33 symbols of eight bits, which include six audio samples, plus the 27 sync bits. As there are 7,350 frames per second, this gives us the $6 \times 7{,}350 = 44{,}100$ samples per second that we have previously noted.

Now, the audio samples are not recorded in succession, they are interleaved with those of an adjacent frame by a system of delay lines having a delay time of one frame. Thus frame A is delayed to be concurrent with frame B and the symbols are taken from each in turn. Thus the even ones from A alternate with the odd ones from B. The evens from B are meanwhile delayed so that they in turn are alternated with the odds from C whose even symbols are alternated with D and so on. The interleaving process is thus not just between a pair of adjacent frames, but involves those on either side. It is therefore known as the *Cross-Interleaved Reed-Solomon Code*.

In the playback decoder, the process is reversed, with alternate frames being again applied to delay lines and symbols from each being interleaved, only this time they are really being de-interleaved as the process restores the original positions.

The obvious question is, why go to all that trouble? The answer is that because errors and drop-outs are usually introduced by blobs or scratches on the disc surface, they tend to come in groups rather than being spread out. If frames

were recorded successively, a whole frame or even more could be lost irretrievably. By interleaving them the loss is spread out to parts of several frames instead of one complete one. This enables the error correction circuitry to deal with the errors by averaging from adjacent symbols and other means that we shall discuss presently. It is rather like putting your money on several horses rather than all on one, you are less likely to lose the lot!

SPOT LIMIT

The number of channel bits that can be recorded depends on the diameter of the light spot that scans the disc. It does not have a sharp boundary so the rated diameter is that at which the intensity is at half value of the centre illumination. It is given by:

$$d = \frac{0.6\lambda}{NA}$$

in which d is the spot diameter, λ is the laser light wavelength, and NA is the numerical aperture of the objective lens. For a wavelength of 0.8 μm and a NA of 0.45, the diameter is 1 μm.

A smaller spot size could be obtained by increasing the NA, but this reduces the field of focus and would pare down manufacturing tolerances that are already fantastically small. The focusing tolerance for example is just ± 0.5 μm, less than the wavelength of the light used!

EIGHT-TO-FOURTEEN MODULATION

It follows from the foregoing that there is a limit to the amount of information that can be crammed onto a disc. However, a rather ingenious method is used to increase it although at first glance it would appear to make matters worse.

As is well known, the recording takes the form of a spiral track of pits that are excavated at the back of the disc, after which the rear surface is silvered. The track is read from the front through the transparent disc material, so it appears to the light beam as a track of humps.

The humps are 0.12 μm high, so light reflected from them is shifted by a quarter wavelength compared to that reflected from the surrounding flat areas, which are termed *land*. Interference thus causes darkening as the hump passes, and the effect is increased by diffraction which scatters some of the light, because the hump width of 0.6 μm is smaller than the light wavelength.

A common misconception is that the humps and spaces denote the 1s and 0s of the binary data respectively. This is not so; a 1 is indicated by either a leading or lagging *hump edge*. Such an edge represents a transition from one state to another, light to dark or vice-versa, and it is these changes that the detecting circuits interpret as a 1. What follows whether light or dark, is interpreted as a 0. If the space between two edges, whether hump or land, is twice the unit length, the detector reads it as two 0s, if three times the length, three 0s and so on until the next edge.

A hump three units long thus conveys five digits, 10001. So by adopting this method, more information can be recorded than if each hump was a 1. But this is not the only means used to try and get a quart into a pint pot.

It is obvious that as the spot cannot read two edges at the same time, the hump cannot be shorter than the diameter of the spot. So in the case of a number having different alternate digits (010101...) the unit of space occupied by one digit cannot be made shorter than the spot size. However, if all numbers had say three or more adjacent 0s (00010001; 10001000;...) the space unit allocated to each digit could be shorter, and more information could be packed in.

With the standard binary code of course, this is not so; there are many numbers that have different alternate digits. So although the standard binary code has been used in recording and processing up to this stage before actually modulating the recording laser it is converted to a different code altogether. Tables 1 and 2.

This code has no logical progression like the binary code; it is an arbitrary collection of digital numbers, each being assigned to represent a standard binary number. The important thing about them is that each one has three or more adjacent 0s. A 'dictionary' of logic gates

Decimal	Binary	Decimal	Binary
1	1	60	111100
2	10	64	1000000
3	11	70	1000110
4	100	80	1010000
5	101	90	1011010
6	110	100	1100100
7	111	110	1101110
8	1000	120	1111000
9	1001	128	10000000
10	1010	130	10000010
11	1011	140	10001100
12	1100	150	10010110
13	1101	160	10100000
14	1110	170	10101010
15	1111	180	10110100
16	10000	190	10111110
17	10001	200	11001000
18	10010	256	100000000
19	10011	300	100101100
20	10100	400	110010000
21	10101	500	111110100
22	10110	512	1000000000
23	10111	600	1001011000
24	11000	700	1010111100
25	11001	800	1100100000
26	11010	900	1110000100
27	11011	1,000	1111101000
28	11100	1,024	10000000000
29	11101	1,200	10010110000
30	11110	1,400	10101111000
31	11111	1,600	11001000000
32	100000	1,800	11100001000
33	100001	2,000	11111010000
34	100010	2,048	100000000000
35	100011	2,500	100111000100
36	100100	3,000	101110111000
37	100101	3,500	110110101100
38	100110	4,000	111110100000
39	100111	4,096	1000000000000
40	101000	4,500	1000110010100
41	101001	5,000	1001110001000
42	101010	6,000	1011101110000
43	101011	7,000	1101101011000
44	101100	8.000	1111101000000
45	101101	8,192	10000000000000
46	101110	9,000	10001100101000
47	101111	10,000	10011100010000
48	110000	15,000	11101010011000
49	110001	25,000	110000110101000
50	110010	60,000	1110101001100000

Table 1. Decimal to binary conversion chart. *It is evident from the number of consecutive 1s, or where only one or two 0s are consecutive, that to substitute a 16-digit binary number with one containing no consecutive 1s and no fewer than three consecutive 0s, a much larger number of digits is required, no fewer than 28 in fact. To avoid excessively long words and unnecessarily complex processing circuits, in the cd system the 16-bit words are split into two 8-bit symbols which are changed to 14-bit symbols. By permitting digits to be recorded in a third of the otherwise required space, this* eight/fourteen modulation *saves 25% of disc space.*

digits	decimal max	digits	decimal max
1	1	9	511
2	3	10	1,023
3	7	11	2,047
4	15	12	4,095
5	31	13	8,191
6	63	14	16,383
7	127	15	32,767
8	255	16	65,535

Table 2 Maximum Value: *The maximum value for a given number of digits is when all of them are 1s. The maximum for up to 16 digits are:*

is used to accomplish the conversion in the recording circuit, and a similar one in the player converts the numbers back to binary code for decoding. The numbers are chosen to best suit the architecture of the logic gate chip, but their actual composition doesn't really matter as long as the recording and playback dictionaries are the same.

It follows then, that the unit space for each 0 can be shorter than the diameter of the light spot because it will never encounter a number with less than three 0s. It is in fact 0.3 μm, a third of the light spot diameter. There is a snag though (isn't there always?). You cannot represent all the binary numbers having 8 digits, with another set of 8 digit numbers having no fewer than three adjacent 0s and no adjacent 1s. The new set must be longer. It needs, in fact, no less than 14 digits to represent each 8-digit symbol (hence the designation: eight-to-fourteen modulation). This incidentally is why the original 16-bit words were split into 8-bit symbols; they would otherwise have grown to an unwieldy 28 bits, and the dictionaries for conversion would have been much larger and more complex. Naturally, this increase to 14 bits erodes some of the advantage gained by using shorter space units, and there is a further problem.

There must as we have seen be a minimum of three consecutive 0s, but there is also a maximum. When there is a long run of consecutive 0s there are no light transitions and so there is no signal change. The circuits that count each unit and so determine the number of 0s could thus get out of synchronisation because the pulses provided by the 1s which they latch on to, are absent. The effect is like a tv receiver in which the frame sync pulses are missing due to a fault. The picture remains steady for a second or two but then slowly drifts up or down the screen and starts rolling.

Another effect of a long run of 0s is that the light beam modulation frequency drops to a low value. The servo systems that control the tracking and automatic focusing operate at low frequencies (below 20kHz), so they could be confused by any modulation within their frequency range and thus misfunction.

Because of these effects, the maximum number of consecutive 0s that can be permitted is ten. This is not difficult to arrange when designing the new 14-bit numbers, but a snag arises if a number that concludes with a string of say eight 0s is followed by another that starts with seven. Now we have a string of fifteen consecutive 0s and the maximum has been exceeded. There are quite a few combinations that could exceed the limit of ten. Another difficult situation would be if a number that ended with a 1 or 10 was followed by one that started with a 1. In this case there would not be the minimum of three 0s between the 1s so the spot would be too large to read both 1s.

To overcome these problems three extra bits are added at the end of each symbol. These convey no information and are discarded when decoded in the player, but their function is to prevent consecutive or near consecutive 1s and to break up successive 0s between two following numbers. Their composition depends on whether they are separating 1s or 0s. If more than one combination satisfies the requirements, the one chosen is that which gives the lowest ratio between hump and land length. This ratio is known as the *digital sum value*, and the lower it is the lower the noise in the servo frequency band. The extra three bits are known as *merging bits*.

So the addition of the three merging bits to the 14-bit word extends the original 8-bit symbol to 17 bits, seemingly not a very good exercise in economy and space saving! However, because of the recorded unit being only a third of its otherwise minimum length, there is still an overall improvement in information density of 25%. Without it, the maximum time per disc would be 48 minutes instead of 60. Thus many musical works can be recorded complete on one side of a disc that otherwise could not.

RECAP

At this point perhaps we can pause a little to digest what we have already discussed. The various processes are illustrated in Fig.2 so we will use it to recap. We note at the top that there are six stereo samples in each frame, each consisting of one 16-bit word for each channel, making a total of $2 \times 16 = 32$ bits for the complete sample. These 16-bit words are each divided into two 8-bit symbols to facilitate later processing. Thus we have four symbols per sample, and 24 for each frame.

Next we see that alternate symbols are interleaved with those of adjacent frames on either side, so that errors or drop-outs are spread over several frames instead of concentrated in one or two. This makes them easier to compensate for later.

Eight parity symbols are added in two blocks of four, (of which more in the next section), and also one control and display symbol at the beginning. Next, the 8-bit symbols are converted into 14-bit symbols that avoid consecutive 1s, and enable the space occupied by one digit to be made only a third of the laser spot size. To prevent consecutive 1s between adjacent symbols or an excessively long run of 0s, three merging bits are added at the end of each symbol which are discarded during replay. This brings the total bits per symbol to 17, yet in spite of the extra number an overall space saving of 25% is achieved.

ERROR CORRECTION

A major consideration is the possible loss or corruption of the digital signal due to imperfections in the disc, which considering the microscopic size and the astronomical number of humps in each disc is virtually inevitable. The effect of dirt on the disc surface, though minimised by being out of focus, can also cause loss of signal.

The system of error correction built in to the compact disc is therefore quite elaborate. Firstly, consider how simple corrections of a digital signal can be made by the use of *parity bits*. Imagine a data stream of 8-bit words. Some words will have an odd number of 1s while others will have an even number.

For example, 01101011 has an odd number with five 1s, and so has 01000101 with three. But 01100110 has four, an even number, just as has 01110111 with six. Let us now add an extra bit to each of these so that they always have an even number of 1s. The first number needs an extra 1 and so becomes 01101011<u>1</u>; the second also needs another 1 and thus becomes 01000101<u>1</u>. In the case of the third number it already has an even number of 1s, but as all words must be of the same length it must have an extra digit, so we add a 0. It thereby becomes 01100110<u>0</u>. This applies also to the fourth number which the added 0 turns into 01110111<u>0</u>. We have underlined the added digits which we call parity bits because they put all the words on a par respecting the number of 1s they contain.

Later, after recording the stream, we can get a circuit to check each word for an even number of 1s, and if they are correct, to then ignore every ninth digit which is the meaningless parity bit. If though it finds a word with an odd number of 1s, it knows that the word is incorrect. Of course that doesn't tell us which bits are wrong or how many bits in the word are faulty, but it does identify an inaccurate word.

If the stream represents an analogue audio signal, the faulty word can be erased and its value calculated by taking an average of the adjacent words. The value may not be 100% accurate, but it will not be far out and most likely far closer to the original than the erased faulty word, especially if the defect was with one of the high value digits at the beginning of the binary number. This method of correction, known as *interpolation*, is one of several used with the compact disc, but it is possible to identify and correct the actual faulty digit within the word and thereby reproduce the word correctly.

Such identification can be made by forming the digits into parity blocks. This can best be understood by reference to Fig.3. Here we have for the sake of simplicity three 4-digit words, x1–x4; x5–x8; and x9–x12 arranged in a block. Each has a parity bit added at its end just as before, these being p1, p2, and p3.

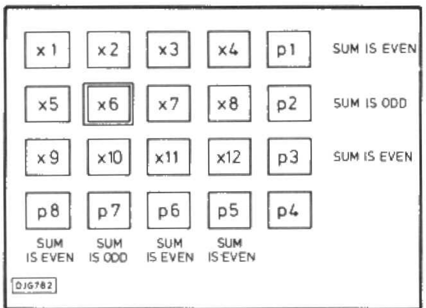


Fig.3. *Block parity. With parity bits added to rows and columns, an odd sum for a row and column identifies the incorrect bit at their intersection*

In addition to these there are parity bits added to the bottom of each column, p8, p7, p6 and p5, with one at the bottom of the column of line parity bits, p4.

The parity bits at the end of each line make each line have an even number of 1s, while those at the bottom of the columns make the columns even. Let us say now that data bit x6 is wrong; this will make the sum of the 1s in that line odd instead of even, and also it will make the sum at the bottom of that column odd. So by identifying the incorrect column as well as the line, the digit at the intersection is positively identified as the culprit. As binary digits have only two values, changing the faulty one to its opposite must make it right. The bit p4 seems redundant, but it serves to check on the other line parity bits as one of those could be faulty just as much as a data bit.

A question may be asked here, how do you convey a two-word dimensional block along a one-dimensional data stream? The answer is like a tv picture, line by line. It is only drawn and described as a block so that we humans can see how it works. The decoder puts the sequence in a memory then sees it as a number of sums; it adds the digits after every fifth bit (end of line), and it also sums the first, fifth and ninth digits, the second, sixth and tenth, the third, seventh and eleventh, and the fourth, eighth and twelfth. When it finds a couple of errors it calculates the intersection and promptly changes the digit there. In the compact disc, blocks are formed from groups of symbols rather than individual digits. This achieves the maximum amount of error correction with the minimum number of parity symbols.

The number of incorrect symbols in a block that can be both identified and corrected in the decoder is limited. However, if the faulty symbols are identified and labelled first, the decoder can correct twice as many.

DECODING AND CORRECTION

As the data stream comes in from the photodiodes, the start of each frame is identified by the synchronising pulses. Next, the 14-bit symbols are converted back to 8-bits by the logic 'dictionary', and the merging bits discarded.

Now the frames are fed into a buffer memory and clocked out at the other end by a quartz controlled clock. The input rate may vary due to wow or other causes, but the output rate is constant so wow can have no effect on the reproduction. The buffer is kept nominally 50% full to allow regulation in both directions, but the actual amount it contains is an indication of whether the motor is running fast or slow. The amount contained is therefore used to generate a control signal for the motor.

The control and display symbol, which is the first of the 33 in each frame is removed and routed to its own circuit. The remaining 32 are then fed in parallel to 32 inputs on the first *of two* decoders. Alternate inputs have delay lines having a delay length of one symbol which thereby restore the interleaved symbols from successive frames to their correct position. The decoder identifies any faulty symbols and corrects one. Two could be corrected here but with a lower degree of accuracy. So if there are more than one, all are given labels and are passed on uncorrected. The parity symbols serve their purpose in the identification and so go no further.

The audio symbols are dispatched to the second decoder via delay lines that space successive samples by 8-frame intervals so that error groups are well spread out and thereby diluted. As the faulty symbols have been pre-labelled by the first decoder, more can be corrected here, up to four in fact. If there are more than that, all are passed without correction but still retaining their labels.

INTERPOLATION

Up to four symbols in each frame can be corrected; beyond this interpolation is necessary. Labelled symbols are erased and their value is estimated from adjacent ones. As odd and even rh and lh channel samples within each frame are interleaved, up to seven consecutive samples can be interpolated. However, owing to the 8-frame spacing introduced by the second decoder, this is multiplied across 56 frames. A two-frame delay line enables a complete frame to be substituted if required, but this reduces the 56-frame capability by two, and delay lines in the recording circuits reduce it by five or six. So reliable interpolation can take place over 48 frames.

This corresponds to some 12,300 data bits or 7.7mm of track length. Distortion increases over the interpolated portion and the bandwidth drops from 20kHz to 10kHz. The maximum burst of errors that can actually be corrected is 4,000 data bits which corresponds to 2.5mm of track length on the disc.

MUTING

Correction and interpolation will cope with the majority of defects and small blobs of dirt. If though a stream of uncorrectable errors occurs that exceeds the capability of the system, the last resort is muting. The gain is reduced so that the aural effect is that of a drop-out rather than a burst of noise which a stream of uncorrected errors would produce. The gain does not drop suddenly as this would produce harmonics and a sharp click. Instead the drop and rise follow a cosine curve. The drop starts from 32 samples before the error stream, and rises 32 samples after it.

SMOOTHING THE STEPS

Following correction, the alternate rh and lh signals are separated and applied via filters to the two d-a converters. This though is not the end of the story. After conversion the analogue wave is in the form of steps at the original sampling frequency of 44.1kHz. These must be smoothed out to reproduce the original waveform, and to remove the harmonics of that frequency which could beat with others such as tape bias.

To cut frequencies of 44.1kHz and upwards, a filter of at least 50dB attenuation is required, yet this must have no effect on frequencies of 20kHz which is little more than an octave below it. This is a tall order and one of the principal headaches for the designer. Complex filters having the desired characteristics are likely to produce ringing or other spurious effects in the audio passband.

OVERSAMPLING

One method commonly adopted for overcoming the filter problem is oversampling. With this, each sample fed to the d-a converters is electronically remembered and repeated before the next arrives. With twice the number of

samples being presented to the converters, the frequency of the samples is obviously doubled, and the process is termed *two-times oversampling*. In many players the signal is repeated four times so giving *four-times oversampling*. The sample frequencies are thereby increased to twice and four times respectively that of the original sampling rate, that is 88.2 and 176.4kHz. The gap between these and the highest audio frequency is much greater than that between the original sampling rate and the audio band, so the filter can have a less steep slope, be less complex, and have less of an effect on the audio signal.

Of course, the number of samples actually recorded per second has not changed, only the fact that each is used four times (in the case of four times oversampling) in the conversion back to analogue. As it stands, this gives four successive identical samples, which means a level step at a quarter of the frequency, in other words we are back to square one with 44.1kHz steps and nothing has really changed.

Oversampling is therefore only effective if the intermediate steps that follow the first of a new sample are varied. One method of doing this as used by Philips is by means of what is called a transversal filter. (Fig.4.) This consists of 24 delay lines connected in series, each delaying the signal by one sampling period, so giving a total delay of 24 samples at the end. Part of the signal is tapped off at each line four times during each sample period, and it is multiplied by a constantly changing coefficient, then passed to an adding circuit. The products of sample and coefficient are thus added to each of the respective quarters of the preceeding 24 signal samples.

The coefficient is a 12-bit word which is added to the 16-bit sample to make a 28-bit word (adding two binary numbers in this manner multiplies them). Its value is chosen for each sample so that the summation does not introduce any extra bits. By this means three intermediate values between the signal samples are obtained.

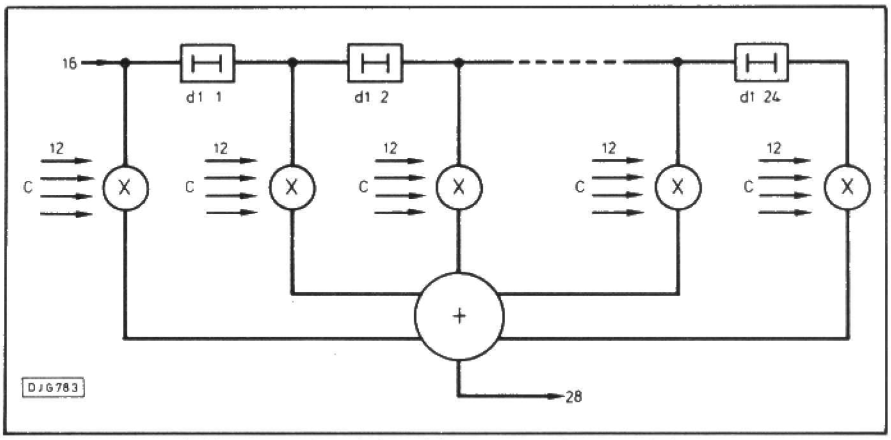


Fig.4. *Transversal filter, signal is delayed for 24 sample periods by 24 series delay lines. Output from each is multiplied 4 times by 12-word constant, and added*

14 OR 16 BITS?

Early 16-bit decoders were quite inaccurate often tending to ignore or falsify the least significant couple of bits. Thus their resolution was no better than a 14-bit decoder, in fact they could be less accurate because their errors were not consistent. Another factor was that 14-bit devices operated much faster than the 16-bit. This permitted the use of oversampling which requires fast operating circuits to handle the high sampling frequencies. Some makers, notably Philips, therefore preferred to use an accurate 14-bit decoder with oversampling.

Quantisation noise is produced in the sampled frequency band which is proportional to the size of the steps. If the step size is doubled by reducing the bit number by one, the noise level is also doubled, so increasing it by 6dB. Thus a basic 14-bit system has 12dB more noise than a comparable 16-bit one, actual values being about −84dB and −96dB respectively.

However, with four times oversampling, the noise is spread over a wider frequency spectrum, so that falling within the audio range is some 6dB less, bringing the noise down to −90dB.

When rounding off to 14 bits, there is a rounding off error which at low frequencies is almost the same as adjacent samples. At a sampling rate of 176.4kHz, most of the audio spectrum is at a comparatively low frequency. This error is stored for one sample period and added to the next sample in antiphase, thus virtually cancelling it out.

The effect is to reduce the distortion introduced by casting off two bits, and also reduce noise by some 7dB. Total noise thus becomes −97dB, marginally better than that of the 16-bit system. Of course noise levels of this order are swamped by the music signal and even by the ambience of the recording studio, so are really of academic interest only. However, it does show that by a little circuit ingenuity, 14-bit players can equal the performance of some using the full 16 bits. However, time marches on and so does technical development. 16-bit decoders have improved since those early ones and it should be expected that they will eventually become standard along with oversampling.

It may be thought that all this complicated messing around with the signal, chopping it up, delaying parts of it, interleaving it, sticking in other bits and pieces, would surely produce a marked deterioration of the result. Well it certainly would if the signal was analogue, but this is the beauty of a digital system. It just records numbers that instruct the dna converter what to produce. You can play about with those numbers and record them any way you like providing they are assembled correctly at the end.

When considering these parameters though it must be remembered that there is a degree of overkill. The excellent BBC music fm transmissions use digital studio to transmitter links that employ only 13 bits and have a high frequency limit of 15kHz. As the upper limit of human hearing is 16kHz, and that only with young adults in their twenties, it can be seen that the cd system has been engineered to give better results than are really necessary.

Conditions in the recording studio, acoustics, microphone placements, and tape editing now have far greater effect on the reproduction than any factor associated with the cd player, other than an actual fault. The same is true for other parts of the domestic side of the system, especially the loudspeakers.

The stereo lp was in its day said by many to be the last word in domestic sound reproduction, so one has to be careful in making similar pronouncements for the cd. It is difficult though to see in what way it could be improved. But on reflection there is one thing. In spite of the mass production of discs and the millions sold, the cost remains far too high. PE

SEEDY CUSTOMER

Heroin-smuggling ring leader Paul Dye thought he was being clever in using a Psion Organiser to store temporary details of deals. Undercover customs officers secretly watched him and saw him using the Organiser on a drug run to Pakistan. When the arrested him they found the Organiser with $65,000 in cash. "It won't do you any good", he boasted, "I've erased everything". With crossed fingers, customs officers took the Organiser to Psion who worked on the eprom memory and recovered an almost complete record of the drug dealings. Had the Organiser used eeprom, like the Philips fts cd player, he might have got away with it. **Ed.**

BATTERY DRIVEN MAINS AND HT CONVERTERS

PART TWO BY GEORGE KERRIDGE

FAILURES ARE MAINLY CHARGEABLE

Car batteries pack a lot of punch and can readily become a versatile power source for short mains failures.

The oscillator circuits looked at so far in part one are all suitable for use in situations where the oscillation frequency is relatively unimportant. As we have just seen such situations can arise where, for example, the end product needed is not an alternating voltage, but a very steady high voltage dc.

50HZ SUPPLY

Let's now move on to a circuit that can be used for driving low power 240Vac mains equipment and which requires an accurately controlled 50Hz frequency.

Certainly any of the oscillators shown can be set to run at 50Hz, but the accuracy with which they can be set and maintained at that frequency is less certain than it perhaps should be. Ideally, we need a very accurately controlled 50Hz source. One way is to use a crystal controlled oscillator. This can drive a sequence of sub-dividing counters, either as multiple chips, or as a chip specifically designed for this purpose.

One such readily available chip is the M706B1. (Fig.18). This is a cmos device designed for use as a 50Hz timebase. To achieve this, a 3.2768MHz crystal is connected across two of the pins, together with a couple of capacitors and a resistor. Circuitry within the chip subdivides the 3.2768MHz clock down to 50Hz. This appears at two outputs as squarewaves of opposing phase. The typical current available at the outputs is only about 7.5mA, but this can be used, via current limiting resistors, as the trigger source for controlling transistor driven transformer windings, as in Fig.8, of part one, for example. It can be operated from a power supply with a range of 7Vdc to 15Vdc.

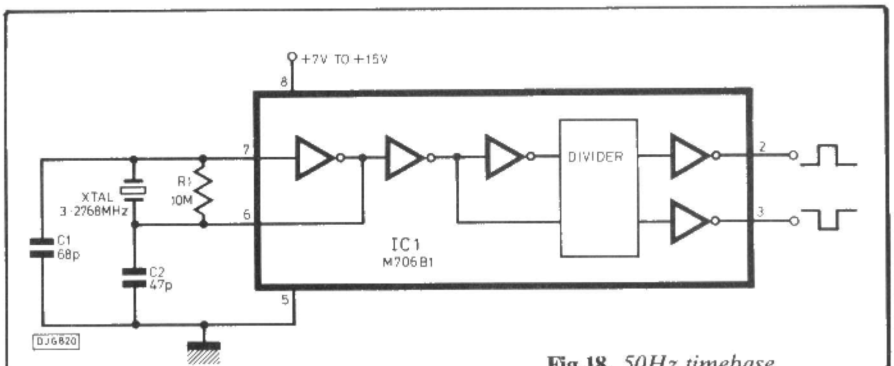


Fig.18. *50Hz timebase*

BATTERY POWER

One point that so far has not been mentioned is the amount of charge available from a battery. It is all very well having a battery to mains converter designed to deliver many amps to all the necessary equipment, but the battery power source is limited.

A battery is quoted as having a charge capacity of so many amp-hours. This means that when fully charged it can deliver that many amps for that many hours. A car battery for example may deliver 12Vdc at 40 amp hours. It should therefore be capable of supplying 12Vdc at one amp for 40 hours, or 40 amps for one hour. During this discharge time though, the voltage will not remain at precisely 12V (even if it was ever at 12V since it could have started off a volt or so higher than this when fully charged). The delivered voltage will gradually fall during use, and so the final converted ac voltage will drop accordingly.

A unit converting 12Vdc to 240Vac to run, say, a 100W lamp, will need a minimum current input to the converter of at least 8A and probably more. The light bulb will thus work for less than five hours with a 12V 40A hr battery. That is excellent for just a short power cut, but the cuts that some of us in the SE experienced in October 1987 far exceeded five hours.

Obviously there is no reasonable possibility of using a car battery to mains converter to power all the lights and other preferred household equipment. It is reasonable though, to use a dc to ac converter just for minimal power consumption for a short period of time. Limiting lamp wattage to just 15W at selected areas of the house is one possibility. (In reality, its probably better to use a car bulb powered direct from a spare car battery for many lighting situations).

Battery to mains converters are also of considerable use for perhaps powering equipment which it is vital to keep running for a short period of time. One such item is a computer, though the power requirement may be heavy. Other suitable candidates for power backup are alarm clocks, telephone answering machines, and even fish tank heaters.

This brings us to the next possibility, that of automatically switching over to a backup supply if power does fail.

CHANGEOVER

Considerable thought was given to possible circuitry for automatically switching a battery to mains converter on and off as required. Several options for the use of thyristors in changeover configurations were explored, but I eventually decided to opt for the simpler, and cheaper method of using a relay for the purpose.

Though relays suffer from a fractional time lag in switching over, they have the beauty of attaining absolute isolation of one circuit from another. Their practice

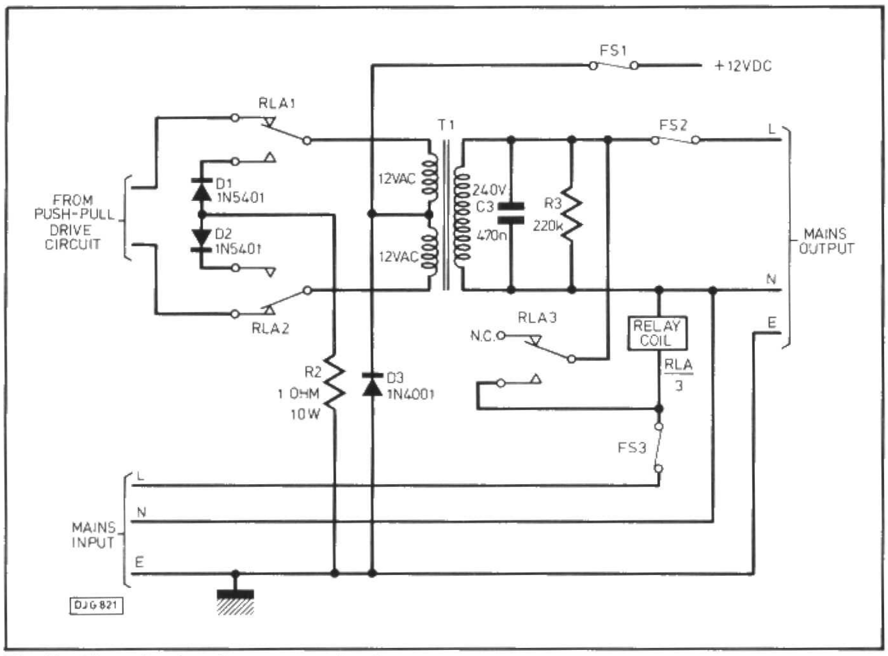


Fig.19. *Use of relay for automatic changeover operaton*

is also more readily understandable for those whose knowledge of electronics is only rudimentary.

Fig.19 shows a suggested relay changeover circuit. The relay coil is of the mains operated type, and only becomes active in the presence of mains supply current. When mains is available the relay contacts switch the live mains line to the output socket. Two other contacts switch the transformer primaries out of circuit from the drive transistors, or darlingtons, and across to two diodes acting as bridge rectifiers. In this mode the mains voltage appears across the 240Vac winding of the transformer and current is transferred to the two 12Vac windings. These pass power through the diodes and resistor to ground. Since the centre tap of the 12Vac windings is connected to the positive line from the battery, the effect is that the battery is put on trickle charge via the resistor. This is a slightly unusual way of doing things, but it works. Fig.20 shows the equivalent circuit.

If the mains power fails or is switched off, the relay coil deactivates and the contacts switch the live line out of circuit from the output socket, and connect the

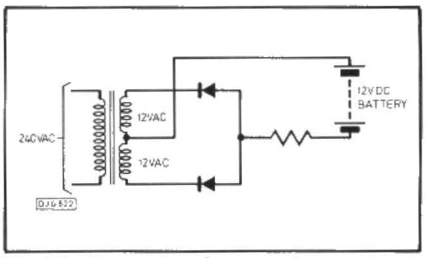


Fig.20. *Equivalent battery charge circuit*

12Vac windings back across the driving semiconductors. This is a good example of the point I made earlier, that a transformer can work in both directions.

Although the oscillator will be operational in either mode, and so consume a small amount of current, the drain is immaterial when the battery is on trickle charge. It also means that the oscillator is immediately ready for control the instant that mains power fails.

MAINS CIRCUIT

Since there are so many options and circuits for generating ac voltages and high level dc supplies, I am only showing a printed circuit board for the simple substitute mains supply.

The circuit as shown in Fig.21 consists of the 50Hz timer in Fig.18, a darlington drive circuit, and the transformer and relay circuit of Fig.19. Two additional current amplification transistors, TR1 and TR2, are used between the two, enabling the use of darlingtons capable of sinking up to 20A each from a 12Vdc supply. With the correct choice of transformer, the final output could supply up to about 200W at 250Vac rms. (To achieve the full current rating of TR3 and TR4 it may be necessary to change TR1 and TR2 for types capable of delivering greater drive current).

Note that the oscillator and the centre tap of the transformer could be fed from different batteries if preferred. The transformer supply may also be at a higher voltage level than the oscillator if the situation demands (but not at a lower one). For example, the main current might need to come from a 24Vdc battery, in which case the transformer and darlingtons must be selected to suit the supply. The oscillator would then run from another dc supply between 7V and 15V, provided that this is equal to or less than the main battery supply.

The automatic changeover circuit has not been allowed for on the pcb shown in Fig.22 and the relay should be fixed to the case chassis. If the relay is not used, the relevent links on the pcb should be connected. Although the darlingtons are mounted on the pcb ***THEY MUST ALSO BE BOLTED TO HEAT SINKS, OR TO THE CHASSIS. IT IS ESSENTIAL TO USE INSULATING WASHERS*** between them and the chassis to prevent them shorting out the supply. The battery charger diodes D1 and D2 may get warm during charging and so should be mounted slightly above the pcb. R2 will probably be supplied in a heat sink mount and should be bolted to the case.

Two other important points are that the diodes on the base of each darlington should be included to suppress inductive spikes. The capacitor and its associated resistor across the 240Vac winding must also be included for similar reasons. It should also be noted that despite the capacitor and inductive nature of the

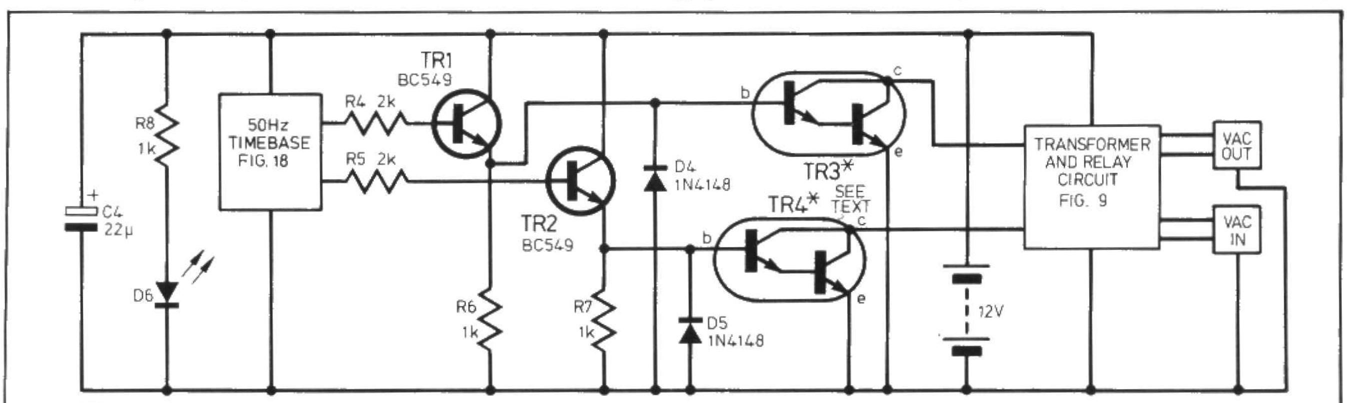


Fig.21. *Battery to 50Hz mains converter*

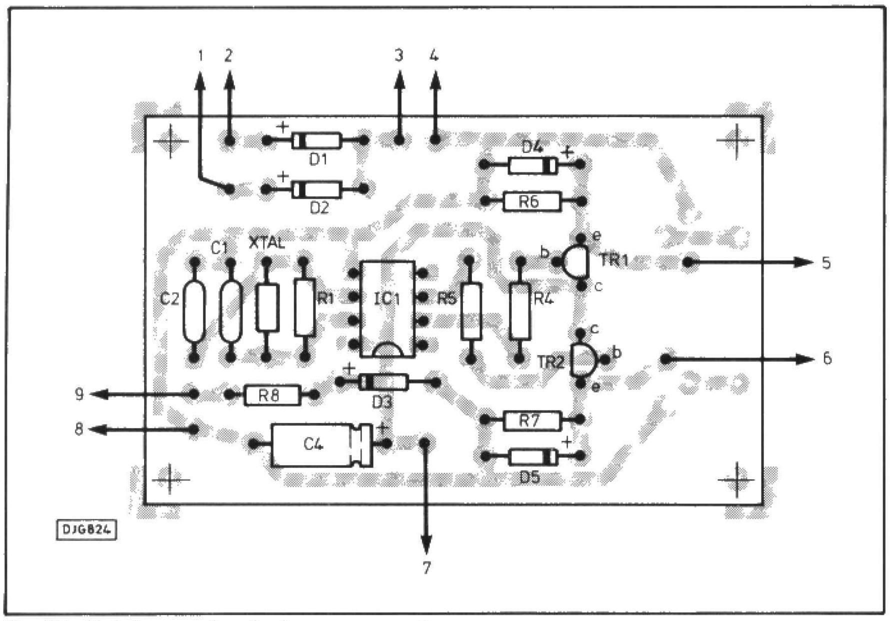


Fig.22. *Pcb layout for the battery to mains converter*

COMPONENTS

RESISTORS
R1 10M
R2 1Ω 10W
R3 220k
R4,R5 2k (2 off)
R6-R8 1k (3 off)

CAPACITORS
C1 68p
C2 47p
C3 470n 250V min wkg.
C4 22μ16V (or larger)

SEMICONDUCTORS
D1,D2 IN5401 3A 100V (2 off)
D3 IN4001 1A 50V
D4,D5 IN4148 (2 off)
D6 led
TR1,TR2 BC549 or similar npn (2 off)
TR3,TR4 MJ1004 175W 20A npn darlington, or TIP132 70W 8A npn darlington, or select to suit needs (see text). (2 off)
IC1 M706B1 50Hz time base

MISCELLANEOUS
XTAL 3.2768MHz crystal
T1 0-12V 0-12V transformer at current to suit needs, max 20A
FS1-FS3 Fuses and holders to suit current (3 off)

Mains input and output sockets, 12V heavy duty battery, heat sinks to suit TR3 and TR4, relay 240Vac 3pco contacts to suit current, battery input socket, case to suit, connecting wire to suit currents concerned, printed circuit board 286A.

CONSTRUCTOR'S NOTE

The PCB is available from Phonosonics, 8 Finucane Drive, Orpington, Kent, BR5 4ED.

transformer, the output waveform will not be a pure sinusoid, though it will be far more rounded than the squarewave input.

Remember when testing or using this circuit that mains ac voltages will be present and adequate safety precautions must be observed at all times. The stepped up supply can be just as hazardous as that coming from the normal mains. If in doubt seek qualified advice.

EXPERIMENTAL BOOSTER

I have shown a fair selection of possible circuits for generating both ac and dc high voltage supplies from a battery source. Any of the circuits can be modified by using alternative components to suit individual needs of frequency, current and voltage. I will conclude by showing one other circuit that should make interesting experimenting, in Fig.24.

It is a variation on the cmos inverter circuit, but uses a ferrite inductor as both voltage amplifier and frequency control component. The value of the inductor determines the feedback frequency from its output via the resistor back to the first inverter. Each of the subsequent inverters acts as a high gain amplifier that keeps the circuit oscillating. The ac output voltage level from the inductor can rise to several hundred volts under the correct conditions. The three main factors are the inductance and output capacitance values, and the load put on the inductor's output. The load also includes that of the feedback resistor, and of any attached monitoring equipment.

It will appear at first sight that this full voltage will appear at the input of the first inverter. In practise the swing at that point is only a few millivolts due to the limiting factor of the resistor.

It is a circuit worth experimenting with. Try varying the inductance, capacitance and resistance values, as well as the output load applied. Be sure to keep the suppressing diode in circuit prior to the inductor to avoid killing the chip — the inductor could produce an adverse voltage at the input to the inductor if a significant current or voltage change occurs on the inductor's output. It's best to have a spare chip or two available in case of experimental mishaps! The variable resistor is used to vary the maximum output level from the inductor.

This last circuit is one which I have used as the ht source for powering an

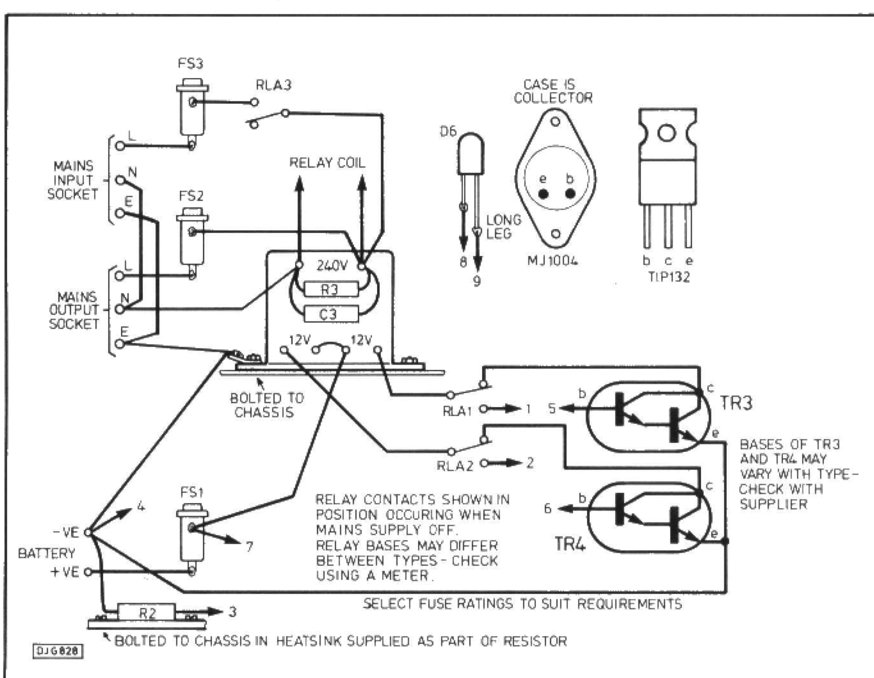


Fig.23. *Wiring details for the battery to mains converter.*

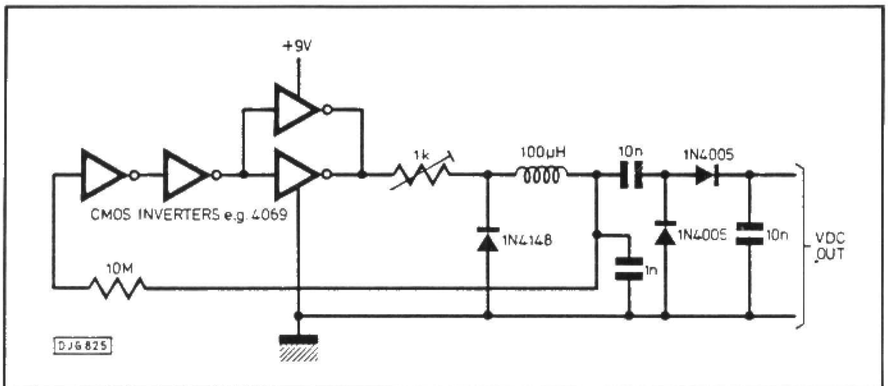


Fig.24. *Experimental dc to ht generator*

experimental geiger counter. There are probably other uses for it where a high voltage is needed at only a very low current. The final ht can be further boosted by feeding the output to a voltage multiplier circuit, like those in Fig.16. One area in which a negative ht version might be exploited is in air ioniser circuits.

SUPERCHARGED

What ever application you have in mind for battery to ht generators I hope that I've given you food for thought. Remember, though, to keep your batteries charged! PE

SUB-AQUA TV

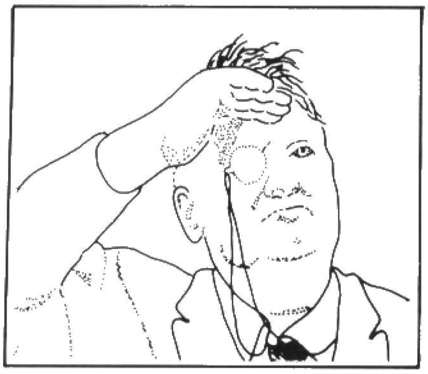
Scuba diving and watching nature programs on tv are a couple of my many addictions and so it was with great interest that I followed the Reefwatch programme on BBC1 in May. The waters off Eilat are famous for their clarity and variety of colourful sealife, and the live underwater tv images were superb.

I was also interested to see how the deeper the cameras went so, as divers will know, the red end of the colour spectrum gradually diminished. At one point it seemed that the divers were getting very deep and I was beginning to speculate on the length of the camera cables. The scene then cut back to the surface and it looked as though night was falling. In the middle of the day?

My mind then surfaced as well and it dawned on me that it was the Box at fault and I could smell that old familiar "something's shorting!" aroma. With wife about to wail "thar she blows" I dived for tv mains plug before Armageddon acquired domestic relevance. But no burning fiery furnace was about to erupt – it was a leaking flower vase on top of the tv robbing the Red Sea of its ordained hue. Through a crack narrower than Moses' parting, water was seeping through the vase and trickling deep down among the circuits. And into the pot that presets the red balance, which was progressively losing track of its intended resistance.

Fan heaters can be a vital part of workshop repair gear (nearly as important as a hammer) and a couple of hours of forced warm draught reinstated the drought conditions preferable to hitech vision. Thankfully, the screen returned to its rainbow tints without a trace of water colour. Can't help but wonder, though, how many tv engineers make their living because of leaking floral displays on top of goggleboxes. And I guess their maintenance manuals must be brimming with flow charts ...

Ed.



SPACEWATCH

BY DR PATRICK MOORE

OUR REGULAR LOOK AT ASTRONOMY

The family castle is up for sale, Hubble faces trouble in space and on the ground, and a star has been discovered which is about to vanish ...

Despite the virtually unanimous opposition from all astronomers, Herstmonceux Castle has finally been offered for sale, and there now seems no hope of retaining it as the site of the Royal Greenwich Observatory. The RGO itself is to move to Cambridge. Presumably the priceless Library and archives will be either pigeonholed or (more probably) dispersed; the Exhibition will dismantled; the training of young astronomers will cease, and what will happen to the telescopes of the Equatorial Group is anybody's guess. Neither do we know the cost to the country, though £6,000,000 is a reasonable estimate. What the advantages are can be explained only by the Science and Engineering Research Council!

As one staff member of the RGO said, the only course now is to salvage what can be salvaged from the wreck. It has been said by the SERC that the Royal Greenwich Observatory will remain a separate unit. Pessimists forecast that within a few years it will quietly vanish, to be absorbed into the astronomy department at Cambridge University. Time will tell.

On a brighter note, NASA has announced that it proposes to start planning two important space missions for the 1990s. One is a rendezvous with a comet and an asteroid. The other is the Cassini mission to Saturn (named in honour of the Italian astronomer G.D. Cassini, the leading planetary observer of the 17th century, who discovered the Cassini Division in Saturn's rings as well as four of the planet's satellites, Iapetus, Rhea, Dione and Tethys). The Cassini mission will pay particular attention to Titan, which I discussed in my article last month.

Pulsars continue to surprise us. The latest novelty is a pulsar in Sagitta, PSR 1957+20, which has been studied from Arecibo by a team consisting of A. Fruchter, D. Stinebring and J. Taylor. It is a rapid pulsar, rotating 622 times per second, and every 9 hours is eclipsed by an invisible companion, remaining obscured for 45 minutes. Apparently the invisible companion has a diameter 1½ times that of the Sun, but no more than 3 per cent of the solar mass; the two components are very close together, and the companion may be a 'brown dwarf', intermediate in type between a true star and a Jovian planet. It is suggested that its outer layers may be in the process of being stripped away by the pulsar and dissipated in space, so that eventually — in no more than a thousand million years or so — the companion may have been completely destroyed. The idea of an evaporating star is certainly new, but it does seem to be a strong possibility.

The Sky This Month

The summer of 1988 is a reasonably good time for planetary observers. Venus dominates the morning sky, and by the end of July it rises about two hours before the Sun; it is then far brighter than any other celestial object apart from the Sun and the Moon, and will be about 40 per cent illuminated. Also in the morning sky are Mars — still rather low, but brightening steadily — and Jupiter, which will have risen by midnight. Mercury is officially a morning object, though it is so far south of the celestial equator that British observers are not likely to see it with the naked eye.

Saturn, which reached opposition last month, is still very much in evidence, and the rings are wide open, though unfortunately the planet is inconveniently low down, and southern observers have the best of matters (as so often seems to happen!).

The Moon is new on July 13, and full on the 29th. There are no solar or lunar eclipses this month.

The annual Perseid meteor shower beings at the end of July. This will be a favourable 'Perseid year', because when the shower is at its peak, around August 12, the Moon will be new and will cause no interference. I will have more to say about the Perseids next month.

Among the stars, the evening sky is graced by the so-called Summer Triangle, with the brilliant blue Vega almost overhead after dark and the other two members of the Triangle, Deneb and Altair, also very much in evidence. The three are at very different distances from us. Altair is 16½ light-years away, Vega 26 light-years and Deneb as much as 1800 light-years. It follows that Deneb must be the most luminous, as indeed it is — perhaps 70,000 times as powerful as the Sun.

It is interesting to reflect that so far as Deneb is concerned, the Earth is still 'radio quiet', and will remain so for well over 1500 years yet; but to Altair and Vega, we are already 'radio noisy'. If we assume the highly improbable — that there are inhabited planets in these two systems, and that they have radio receivers capable of picking up our transmissions — denizens of Altair will now be receiving our broadcasts of 1972, while those of Vega will be receiving our broadcasts of 1962.

Actually, Vega is one of the stars found to have a huge infra-red excess, indicating the presence of cool material which may be planet-forming. Altair is different, and is distinguished by its very rapid rotation; even though no telescope will show it as anything but a speck of light, we know it to be egg-shaped.

During July evenings the Great Bear is in the north-west, while this is the best time to see Antares, the red supergiant in Scorpius, and the lovely star-clouds of Sagittarius which hide our view of the mysterious centre of the Galaxy. In the east, the Square of Pegasus is starting to come into view by midnight. Arcturus, the brilliant orange star in Boötes (the Herdsman) is still prominent in the north-west; to find it, follow round the 'curve' of the Great Bear.

THE HUBBLE TELESCOPE: NEW MISGIVINGS

Scientists everywhere await, with impatience, the launchings of the Hubble Telescope — a reflector with a 94-inch mirror, to be put into a path round the Earth. Operating from above the atmosphere, its performance will far surpass that of any telescope on the surface of the Earth.

The Hubble Telescope should have been in orbit long before now. Like everything else, it was delayed by the Shuttle tragedy. New schedules were announced regularly — and, just as regularly, revised. The situation was akin to that experienced by passengers awaiting the departure of a British Airways flight 'delayed by the late arrival of the incoming aircraft', though with the Hubble Telescope the delay amounted to months or years instead of hours!

Now, the launch date for 1989 has been questioned yet again. There could be a further prolonged delay. And in any case, there is another problem to be faced: the Sun.

Solar minimum is past, and activity is picking up again; during the first part of 1988 there have been several major spot-groups, one of which produced a good display of aurora. It is never easy to forecast the time of maximum, but it looks as though we may be thinking about 1990 or 1991 — just the time when the Hubble Telescope will be in full operation. But as is well known, increased solar activity makes the Earth's upper air expand, and the density at any set level increases, which also means increased drag (this is why the Skylab space-station came down before NASA expected, scattering fragments over Australia, though it must be added that our own expert, Desmond King-Hele, had given ample warning). If there is a marked increase in atmospheric density at the altitude of the Hubble Telescope, there may be a need for 're-boost' after only a few months in orbit, which would cause serious complications.

What are the alternatives? It may be that the Hubble Telescope can be put into an orbit higher than that originally planned. It may be that the danger is less than feared. On the other hand, there is always the chance that the launch will have to be put off until after solar maximum. The trouble here is that the telescope itself is already deteriorating because of the long delay. Indeed, the scientific consequences of the Shuttle disaster have been dire. PE

Ring in the View

View-as-you-chat has come a step closer according to recent report from the Far East. It seems that Japanese manufacturers have come to an agreement on standards for video telephones.

Mitshubishi and Sony have already introduced video phones, which although currently conforming to different formats, will eventually comply with the new agreeement.

It seems that live video pictures of callers are still some way off and that the present technology only allows for single still pictures to be transmitted. The restricted bandwidth of domestic telephone lines limits the transmission rate to between five and six seconds, and apparently the users must not speak during picture transmission.

For the moment I feel that video phones will have more novelty value than practical purpose. Once they become higher quality real-time systems they will undoubtedly find wide spread appeal. In the meantime I am thankful that I can still answer a phone early in the morning without having groped for a razor first. **Ed.**

I DON'T ALWAYS AGREE

BY WAYNE GREEN

VIDEO MAY TURN THE PAGE OF HISTORY

Disagreement often results from misunderstanding. With the aid of video text books low cost education could breach the frontiers of illiteracy and ignorance, broadening the horizons of knowledge

"I DON'T ALWAYS AGREE ...". That's the chorus of my readers here across the Pond. "I enjoy your articles but I don't always agree with them."

I want to know "why the hell not?". If readers don't agree, is it because I'm wrong ... or are they? Now, if they've done their homework and have the facts to prove I'm wrong, I want to know about it. Or am I up against them substituting conviction for information? It's a great deal easier just to believe in something than to understand it. Perhaps that's why you don't see many scientists in politics.

SPEAKING IN POLITICS ...

You may recall that recently I ran for Vice President of the USA, in the New Hampshire primary. Pulled 32,000 votes — more than many names you'll know in Britain. More than DuPont, Gephardt, Jackson, Hart, and so on ... Ha!

They spent zillions in tv promotion and advertising — I spent zilch, merely going around the State, speaking to Lions, Rotary, Chambers of Commerce, etc, explaining the need to revamp education and build electronics and computer clubs as a way to get youngsters interested in technology and communications. You in Britain could learn a thing or two as well.

QUALIFYING EDUCATION

Education, I feel, is America's most serious problem. The latest national Science Foundation report states that the education provided to American kids puts the US dead last in a 13-country list. There are many things which need to be done to improve the American education system, and yours too I'll bet. My proposed electronics course being but one.

My proposal even gets around the lack of qualified science and maths teachers — which could add a minimum of ten years to any teaching project. US teacher's groups have been fighting off technological aids to education with surprising success. I'd encourage the development of home education and

educational support systems — testing new ideas and using those that work the best. I'd sure want to encourage the development of a series of videos to help people get their education certificates — to help functional illiterates learn to read and write, even to pursue special interests.

VENI, VIDEO, VICI

Once we've teaching systems that work, we'll be ready to start selling these to other countries — in English and in the native language. This could make it possible some day for even the smallest country to provide a high quality education from the first grade right through college graduate work, and at a reasonable cost. Now that could really change the whole world!

Having visited many third world countries and talked at length with electronics diy-ers living in them, I'm familiar with their special problems: educational, political, social. I know of no simpler solution than education to what ails these countries.

A first class, low cost education would be far more valuable than economic and military aid, and incredibly less expensive. Though it wouldn't be all that popular with many dictators.

If we can get the fundamentals of electronics into our schools we'll be on the road to regaining our lost consumer electronics industries back from the Far East. Perhaps if we can get more kids interested in the excitement of amateur electronics, we can break the pattern of mediocrity that locks so many people into lives of so little value to themselves and the world. Perhaps, if we try, we can rescue kids from turning into human plankton and turn them into scientists.

PRACTICAL VIDELECTRONICS

Let's imagine the text book of 1999, less than eleven years from now. I see it as a monthly video magazine, making it possible for the material to be up to date in a way never even imagined for text books. In the monthly text on the fundamentals of electronics is a chapter on how alternating current was invented by Nicola Tesla — the brilliance of his idea and how it solved the problems of delivering electricity over long distances.

Another chapter might discuss the foundations of computer languages and chip instruction sets. Then there'd be a column on project building suitable for kids of any age, maybe even a review of some new superconductivity kit, or whatever the latest discovery is by then. Of course there'd be a column on school computer clubs — perhaps encouraging them to network with other school clubs via ham radio or the phone. I'll bet we could generate a generation of science hobbyists.

DXING ELSINORE?

Of course this could unleash a lot of new hams and cb fanatics. With millions of kids in each grade, all exposed to the ham virus via a ham column, who knows? We might have a million hamlets running round with df gear, going on treasure hunts every weekend. Other kids would be doing videos for fun to swap with other school video clubs ... making more hams. Young hams would be expanding our satellite communications, setting new records for miles per watt, working hundreds of countries

CONTINUED ON PAGE 53

SEMICONDUCTORS

PART 9: PRACTICAL THYRISTORS AND TRIACS BY ANDREW ARMSTRONG

TRIGGERING CIRCUITS

In many triac applications, circuitry kept at earth potential for safety generates the mains control signal via a triac. Several ways of isolating the signal circuitry are possible, and in some cases isolation is not required at all.

Part 8 published last month considered only the theoretical aspects of thyristors and triacs. This month we shall look at some practical circuits and building blocks.

First of all, I shall return to the gto (gate turn off) thyristor. The triggering waveform shown last month was highly idealised, and in practice nobody would bother to generate such a waveform. The negative signal needed to switch off a gto can be generated easily and automatically by using a pulse transformer.

Switching on the current to the trigger transformer produces a positive signal on the secondary of the transformer, and this triggers the gto. When the gto must be switched off, the current to the primary of the pulse transformer is switched off, and the resulting back emf on the secondary switches off the gto. It is important to connect the pulse transformer with the correct polarity.

Fig.82 shows a horizontal deflection output stage for use with a small cathode ray tube. The section of circuitry is shown three times for comparison, with a bipolar transistor, a power mosfet, and a gto. The zener diodes to limit the voltage spike are beneficial in each case, but note that the power mosfet does not need an antiparallel catch diode.

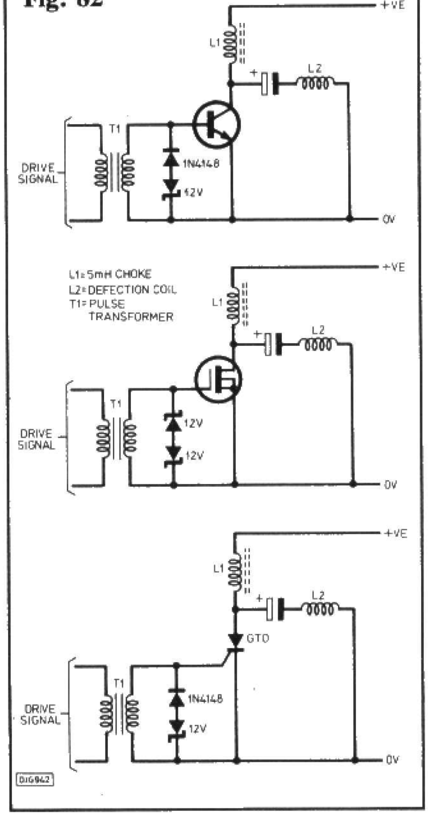
In each case the negative voltage generated on the output of the pulse transformer when the primary current is switched off is useful. It removes charge from the base region of the transistor, or discharges the gate capacitance of the power mosfet, or switches off the gto.

This is a particular application for which three very different devices are all suitable. It is likely, however, that for higher powered circuits of a similar type the gto would be most suitable. On the other hand, the switching speed of the gto is limited, so that at higher frequencies such as those encountered in switched mode power supplies the gto would not be suitable at all.

ISOLATION

A more important aspect of the pulse transformer is that it provides isolation between control circuitry and high voltage circuitry. Pulse transformers are often used to separate triggering circuitry from triacs connected to the mains. It is even possible to connect the triac in series with the live connection to the load instead of the neutral one, thus slightly enhancing the safety of the circuit.

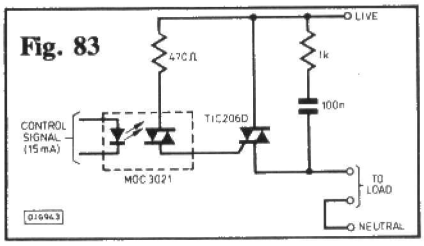
Fig. 82



A word of warning here. Though it is safer, if all else is equal, to connect a triac in the live rather than the neutral line, a triac cannot be relied on to isolate a load from the mains for safety purposes.

Another means of isolating control circuitry from the mains is to use an opto-isolated triac. For low currents the opto-isolated triac can do the work on its own, otherwise it may be used to trigger another, more substantial device. This application is illustrated in Fig.83.

Fig. 83



Some opto-isolated triacs incorporate zero level triggering circuitry, so that they will only switch on near to a mains zero crossing, and thus avoid generating interference. It is, of course, impossible to phase control a load using this type of isolator.

To assist in choosing thyristors and triacs, three tables of data are included at the end of the text. Table 5 covers thyristors, Table 6 covers triacs, and Table 7 covers optoisolated thyristors and triacs.

DIMMERS

One application in which isolation from the mains is not normally a requirement is the light dimmer. In this application, safety isolation is provided by the plastic spindle of the control potentiometer. Most domestic light dimmers are housed in plastic cases which provide adequate protection from live circuitry.

Domestic lamp dimmers use an rc network to provide a phase shifted signal derived from the 50Hz mains. The signal is used to trigger the triac via a diac.

A diac is very much like a triac but without the gate terminal. It is made in such a way that it will break down and trigger itself when approximately 30V appears across it in either direction. The circuit shown in Fig.84 illustrates this principle. When the voltage on C1

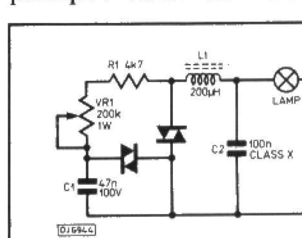


Fig. 84

reaches 30V the diac switches on and discharges C1 into the gate of the triac. This switches the triac on, which in turn switches on the lamp. Once the triac is switched on, no further current flows in R1 and VR1, so minimising their dissipation.

Clearly, the soonest that the triac can be triggered during a mains half cycle is when the mains voltage has risen to just above 30V. This means that there is a small part of the mains cycle during which the triac cannot be triggered. This is not a serious handicap, because very little energy is contained in this tiny fraction of a cycle. Furthermore, if the triac were to be triggered by a brief triggering pulse such as would be generated by the discharge of C1 via the diac, it would not remain on. At very low voltages the load current would not reach the holding current of the triac.

Note that this circuit includes suppression components to filter out interference which would otherwise be transmitted down the mains wiring. The time constant of L1 and C2 is chosen to reduce ratio interference to levels which would normally not cause a problem. Omission of these components would result in serious radio interference. The interference would be at its worst when the triac is triggered at the peak of the mains half cycle, ie approximately 340V.

This simple light dimmer circuit suffers from a hysteresis effect. The problem is that not all the charge is removed from C1 between one trigger pulse and the next. Consequently the trigger point on one half cycle affects that on the next and so on.

The amount of charge remaining on C1 at the end of a half cycle depends in part upon the load resistance. The load is a lamp whose resistance depends upon its temperature. You see the hysteresis effect in the following way: the lamp dimmer must be advanced to a substantial brightness setting before the lamp comes on. Then the dimmer may be backed off to achieve a lower brightness level.

The circuit shown in Fig.85 uses an extra rc time constant to improve the situation. This circuit provides smoother control.

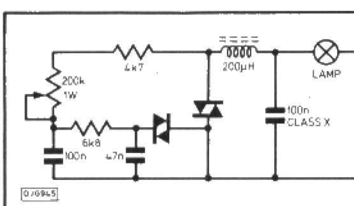


Fig. 85

ISOLATED CONTROL

As mentioned earlier, it is often necessary to operate control circuitry at earth potential, while the triacs being controlled are connected to the mains. There are many different approaches to the problem, depending on the precise application, but the method with the widest usefulness is probably the opto-isolated triac.

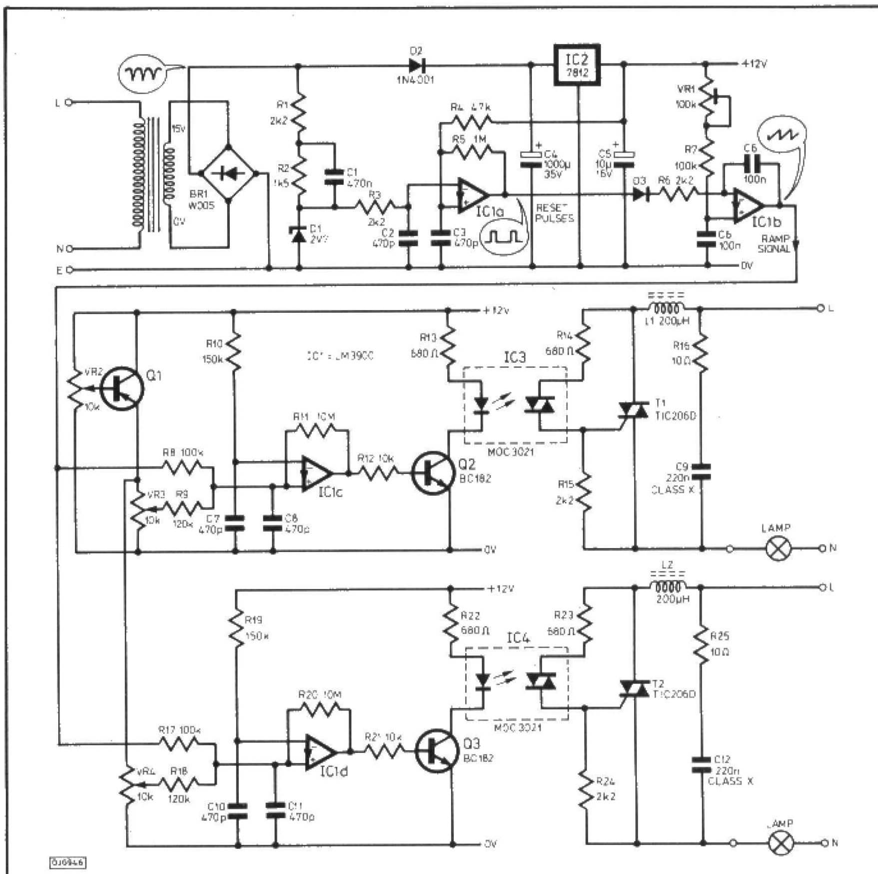


Fig. 86

The circuit shown in Fig.86 illustrates this principle, using opto-triacs to phase control two lamps. This design features two channels in which the brightness is controlled by a voltage. In the circuit shown the control voltage is provided by two potentiometers, with a master control provided to dim both channels simultaneously.

If this principle were extended to further channels it could provide a simple stage lighting unit. If instead the control voltages were derived from audio signals then the design could provide a very effective sound controlled light unit.

The principle on which the unit operates is to generate a repetitive ramp waveform synchronised to the mains. The ramp generator is reset around the mains zero crossing, and continues to ramp up until the next reset pulse. The ramp and the brightness control signal are added together via two resistors to produce a current to feed into the input of a Norton opamp. This current is compared with a current fed into the other input of the opamp. The size of the ramp is adjusted so that the ramp on its own does not quite switch the comparator, even at its tip. The addition of just a small brightness control signal causes the comparator to switch near the tip of the ramp, and bigger brightness control signals cause earlier triggering.

The top part of the circuit is the power supply and ramp generator. IC1a is used as a comparator to generate reset pulses whose timing is determined by the rectified but unsmoothed dc on the output of the bridge rectifier. D2 serves as a blocking diode to permit smooth dc on one side and unsmoothed on the other.

Because the timing information is derived via a mains transformer, rather than straight from the mains, this is not necessarily in perfect phase with the mains. Typically mains transformers give between 5° and 10° phase lag. This can cause problems if a very narrow reset pulse is used, because the tip of the ramp can trigger the triac on the mains half cycle *after* the one on which the ramp started. To avoid this problem a certain amount of phase advance is given by C1.

D1 limits the voltage excursion to a level which will not damage the input of IC1a and both inputs of the opamp are protected from interference by 470pF capacitors. The net result is a clean ramp reset pulse with the correct timing. This pulse is used to reset an integrator which ramps up to approximately 7V during one half cycle.

At first sight the integrator may look a little strange; this is because the circuit is using a Norton opamp, whose inputs operate on current rather than voltage. That is to say that the output voltage of the opamp is equal to its gain times the

difference between the two input currents.

The inputs both have the characteristics of silicon diodes with the cathode connected to 0V. While the opamp is operating linearly with negative feedback, it acts to maintain equal currents into its two inputs. Thus the charging current for C6 must equal the current fed into the positive input by R7 and VR1.

When the reset pulse arrives, a very large current is fed into the negative input which causes the capacitor to discharge rapidly and the output to go to 0V. Once all the charge is removed from the capacitor the diode effect on the opamp light terminal prevents reverse charging from occurring. This means that the integrator starts to ramp up as soon as the reset pulse finishes. Norton opamps will be covered more fully later in the series.

MASTER CONTROL

As mentioned above, the ramp signal is added to the brightness control signal. The brightness control signal itself is derived from a potentiometer whose top end is fed from another potentiometer via a transistor to increase the current capability. This method can be used to feed any reasonable number of secondary control pots from one master pot.

The ramp and brightness control signals are fed to a Norton opamp connected as a comparator. Its inputs are protected from interference by 470pF capacitors as with the reset pulse comparator.

When the comparator output switches high, the transistor, Q2 or Q3, is turned on, and this switches on the opto-triac, IC3 or IC4. This in turn triggers on the main triac which carries the load current. Because this is a phase control circuit, it can generate a lot of interference, so inductors are used in series with the output to filter out radio frequency interference. A 10μ resistor is included in series with the filter capacitor, to damp the circuit and prevent possible resonance problems.

The TIC206D triac is guaranteed to trigger with a gate current of 5mA, except in quadrant four, when it may require 10mA. It will not be used in quadrant four in the circuit, but only in quadrant one and three, so it is capable of being triggered via its gate current limiting resistor, even when the mains is near to the zero crossing point. To prevent leakage in the opto-triac from spuriously triggering the TIC206D, a gate leakage resistor, R15 or R24, is included.

This circuit has not been tested as it is drawn, but all the element of it have been used in other contexts in the past. Should you wish to build this circuit on Vero board, take care that a stray uncut Vero track does not nullify the isolation of the opto-triacs. If in doubt, cut holes in tracks adjacent to tracks carrying mains for extra safety.

The rfi filtering inductors L1 and L2 may be made by winding about fifty turns of 0.5mm diameter wire onto a piece of ferrite rod salvaged from an old radio set. A better alternative would be to use a T94-40 toroidal iron dust core available from Cirkit.

Because the timing for the reset pulses is derived from the mains transformer, this component should not be too heavily loaded. For the current consumption of the circuit as shown, a 6VA transformer would be adequate, though a higher rated one would be preferable. If any other circuitry is to be powered from the same transformer, then a higher rated component should definitely be used.

To adjust the circuit for correct operation, set the brightness controls to minimum and adjust VR1 until one or both of the lamps light dimly, then back it off until both lamps are completely extinguished. At the very least this circuit will make a suitable starting point to experiment further with lighting control.

Some sound controlled lighting units flash the lights in time with the music rather than varying their brightness. If these units are designed only to trigger the triacs near the mains zero crossing, no significant radio frequency interference is generated. A filter indicator is not required in such a circuit, though a snubber network is required in order to afford some protection for the triac.

This style of lighting control has the advantages of being sufficiently coarse and obvious for the most hardened disco goer, of not interfering with sensitive sound equipment, and being slightly simpler and therefore more reliable. A possible circuit for a simple zero level triggered lighting control unit is shown in Fig.87.

This circuit shows a simple sound controlled light which will flash a lamp in time with the bass line of the music. The isolation between the audio input and the triac is provided by a transistor-type opto-isolator. The signal circuitry is operated from an ordinary transformer power unit, but the triac triggering circuitry is powered via a mains dropper resistor. The current available from this sort of circuit is given by the formula I(average) = V(peak)/(pi*R). The peak of the mains voltage is 340V and the resistor value is 22k, so a current of 4.9mA is available. This is plenty to power the logic and trigger the triac.

The triac is triggered only on mains zero crossings. Two Schmitt nand gates are used, IC1a and IC1b. When the mains voltage is close to zero, the biasing resistors set the output of IC1a to logic 1 and the input of IC1b not connected to IC1a *also* at logic 1, which means that the output of IC1b is at logic 0. Positive mains voltage in excess of approximately 60V will switch the output of IC1a to logic 0, thus forcing the output of IC1b to logic 1. Negative mains voltages of greater than 60V will register as logic 0, on the other input of IC1b, thus forcing its output to logic 1.

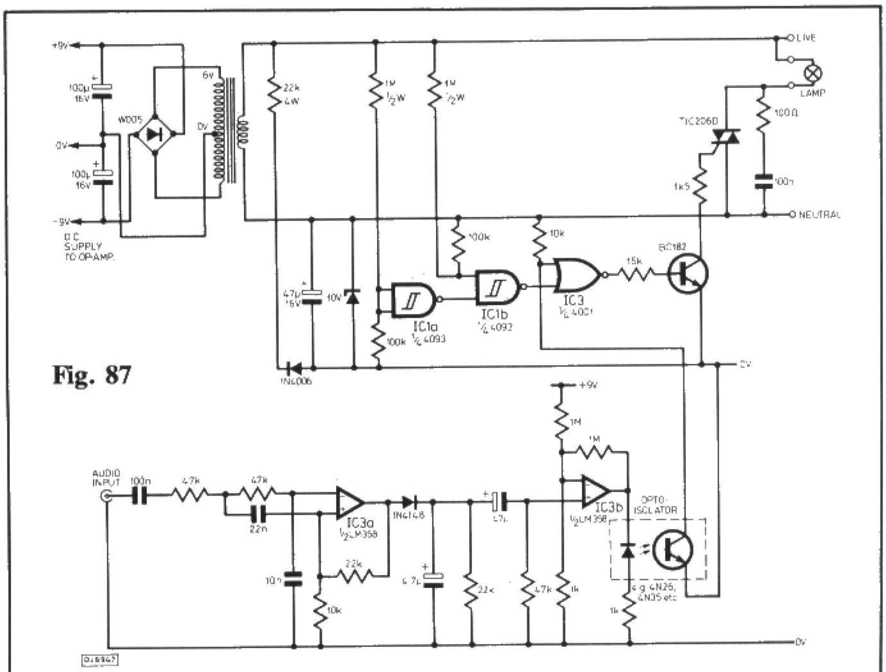


Fig. 87

All this means that on the output of IC1b is a series of brief negative pulses synchronised to the mains zero crossings. These pulses are gated together with an opto-isolated signal derived from the audio signal in order to trigger the triac.

Note that the input protection diodes of the 4093 protect the input of this gate from signal levels which would otherwise significantly exceed the power supply rails. Note also that half watt resistors

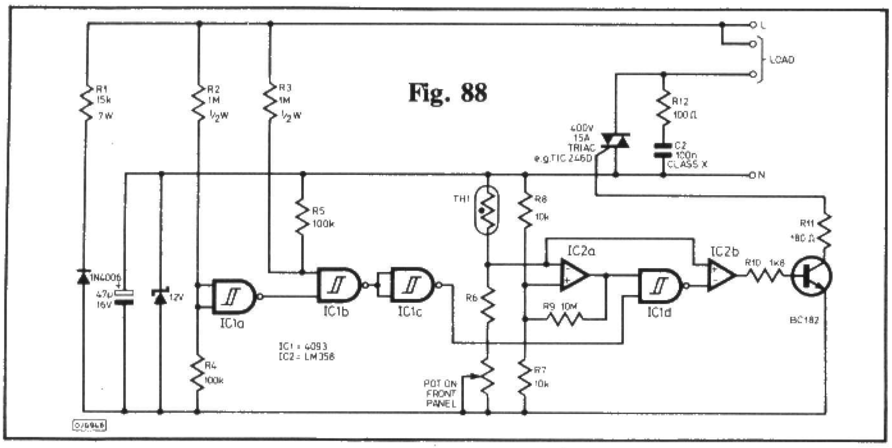


Fig. 88

are used to take a signal from the mains live terminal because most quarter watt resistors are not rated at mains voltage.

The audio signal processing itself is very simple. IC3a is connected as an active low pass filter with gain set at a frequency of 228Hz. Positive half cycles of signal are rectified to generate a varying dc level. This varying dc level is ac-coupled to a comparator, via a longer time constant than that which stores the dc voltage. The effect of this is to provide a sort of automatic gain control in that the comparator will always switch at approximately the average dc signal.

EXPENSIVE THERMOSTAT

Fig.88 shows an electronic thermostat intended for an electric heater. It uses zero crossing detection circuitry just like that of Fig.87. The power to run the circuit comes via a mains dropper resistor, which is a very cheap means of powering a circuit but gives very limited current. Consequently, the design of the circuit has been chosen to use the minimum of current. Brief high current pulses are used to trigger the triac, but these average to a low current over a mains cycle.

The triggering of the triac is turned on or off under control of an opamp wired as a comparator which is caused to switch one way or another by the varying resistance of a thermistor. The output of this comparator is gated together with the zero crossing signal by IC1d. IC2b simply serves as an inverter to get the signal to the correct polarity. Note that a negative power supply is used so that negative trigger pulses are applied to the triac. This avoids operating the triac in quadrant four, where some devices will not trigger.

This circuit must be more expensive than a mechanical thermostat, but it is also more accurate, faster responding, and can be arranged to give less hysteresis. While it is unlikely to be justified for most domestic uses, there may be some occasions on which it is justified. In any event, it serves to illustrate a fairly economical way of designing triac control circuitry.

SOLID STATE RELAY

There is a device available which combines the requirements of isolating the control circuitry from the mains and providing zero level triggering. This device is the ssr (solid state relay). Very often these devices use thyristors connected in an anti-parallel configuration, rather than triacs, to control the mains. This gives a lower voltage drop than an equivalent current rated triac. The voltage drop can be very significant in some ssr applications, not because of loss of power, but because of power dissipation, causing a need for large and efficient heat sinks.

Table 5

Thyristors Type	Cont. current	Surge current	Trigger current	Voltage Notes
TIC106	5A	30A	200μA	Suffix denotes voltage. eg. A=100V, E=500V, M=600V, N=800V.
TIC126	12A	100	20mA	Suffixes as TIC106
BT145-500R	16	300	35mA	500V (Suffix denotes voltage)

Table 6

Triacs Type	RMS current	Surge current	Trigger current	Voltage Notes
TIC206	4A	25A	5MA (quadrants 1 to 3) 10 ma (quadrant 4)	Suffix denotes voltage as TIC106
TIC226	8	70	50mA (quadrants) 1 to 3)	Suffix denotes voltage as TIC106
TIC246	16	125	50mA (quadrants 1 to 3)	Suffix denotes voltage as TIC106
BT134-500G	4	25	50mA (quadrants 1 to 3) 100mA (quadrant 4)	500V Suffix denotes voltage

Table 7 Thyristors & Triacs

Opto Type	Trigger current	Output current	Voltage	Remarks
H11C4	11mA	300mA	400V	Thyristor
H11M1	7mA	300mA	800V	Thyristor
MOC3020	30mA	300mA	400V	Triac driver
MOC3021	15mA	300mA	400V	Triac driver
MOC3041	15mA	300mA	400V	Triac driver with built in zero crossing triggering

For example, if the voltage drop across an ssr is 1.5V, and it is controlling a 30A circuit, the power dissipation will be 45W. A device of this nature is likely to be used in an industrial situation where the ambient temperature may be as high as 40°C. Typically, a maximum case temperature of 80°C may be specified, to achieve which requires a heat sink of better than 1°C/W heat sinking capacity.

One more device which we must mention is the Chipswitch made by International Rectifier. This is a type of solid state relay which uses back to back optically coupled high voltage switching ics whose switching element is a power mosfet. These devices can withstand higher voltage slew rates than triacs without breaking down. They are available in a range of currents and voltages, but the majority are rated for mains operation. These devices are still rather expensive for amateur use, but can be valuable industrially because they can often be used without a snubber network.

This concludes the section on thyristors and triacs. After a month's break, I shall continue the series in the October issue with a look at the design and usage rules which apply to the more common logic families.

PE

BOSFET SSRS

Just as we go to press on Andrew's article on Triacs, International Rectifier have announced the release of two miniature photovoltaically coupled solid state relays. The PVA10 series of SSRS use IR's bosfet power ics and can switch current up to 160mA. They have output capacitances as low as 3pF and switching speeds of less than 25μs, making them ideal for situations ranging from thermocoupling to data transmission. **Ed.**

SPECIAL REPORT

Continued from page 48

with under one watt using digital communications.

REVIEWING KNOWLEDGE

Could all school courses be taught with monthly magazines? Why not? Most subjects can be turned into living experiences. History, for example, can be fascinating. Ask anyone who's read any of the great historical paperbacks that abound. None of that crummy names and dates memorisation screwball. Just think how many great historical movies there are that could be made available on video tape as educational assists!

And at every turn, kids could be encouraged to learn more on their own; to join groups to learn. Kids could research their own city or town history and do their own video on it or put together a book. With desktop publishing becoming so inexpensive and simple, this tool will soon be available to many school students.

Then there's the insect world, much of which has to be studied in depth. Even a monthly magazine type of text would have difficulty keeping up with the kids if they got interested in bugs. You know, in all of history, man has yet to exterminate one single species of insect? And not for having failed to try.

ADDICTIVE

Maths, too, can be fun. Maths is a living science. Every now and then you read of a youngster who's solved some long standing maths problem. When I was in high school we had a maths club where kids enjoyed the challenges of maths together. A video magazine would make it possible to bring the excitement of maths to many more kids.

Betcha, though, if I went on to politics and religion you'd be disagreeing with me again ...

PE

DOWN-TO-EARTH ELECTRONICS

BY TOM IVALL

THE LOCK'S COMPUTERED-UP

Still waters run precisely as deep as they are told to, not a drip less and not a drop more.

The other day I came across a beautiful grey-and-white heron standing solitary in shallow water. It was on a virtual island formed by a sharp loop in the River Thames. I was strolling there to get far from the madding complexities of electronics for a few hours. The heron was mainly interested in fish. Little did either of us know that electronics had already crept up on us. The gently rippling water which the heron was standing in and which was soothing my brain by some kind of meditation process was actually being controlled in level by a sophisticated computer-based electronic system.

We tend to think of the rôle of electronics as being several layers removed from the production of the basic means of life (food, clothing, shelter). Predominantly a technology of information and signal processing, it seems at first to have very little to do with the primary sector of the economy (extraction and application of the earth's resources) and not much more with the secondary sector (processing materials, manufacturing etc). It's certainly prominent in the tertiary sector (services, transport, trade, entertainment etc) and fully at home in the quaternary sector (administration, finance, education, research and other knowledge-based activities). With this general pattern lodged in the mind, it comes as rather a surprise to find electronics working with something so down-to-earth as environmental water.

But when you look a bit closer at what is really happening you find that electronics has applications in all of these sectors. The bulk of the information processing is certainly done in the quaternary sector, but in the others a little bit of processing goes a long way, so in a sense it is more influential. In the Thames system, for example, the entire flow of a river — some 50 million gallons of water a day in the lower reaches — is being automatically controlled on an experimental basis through nothing larger in data processing capacity than an IBM PC computer.

The essential purpose of this scheme, John Walker of the Thames Water Authority told me, is to keep the river at a required level. Written on a table of stone at the TWA are the sacred words: Standard Head Water Level. And the Authority has a statutory duty to maintain this level upstream of each of the 44 weirs on the river. Traditionally this has been done by the lock-keeper at each weir, who opens or closes the weir gates according to the flow rate with the aim of maintaining the SHWL to within ±3 inches.

If the TWA failed to hold this stipulated level the result could be either flooding of the surrounding land at one extreme or grounding and possible damage to boats at the other. Either way the Authority is legally responsible for any damage caused.

"...on a table of stone are the sacred words – Standard Head Water Level...".

Although the SHWL has been maintained by manual control for many years it is an onerous job for the lock-keeper or his relief, requiring 24-hour cover seven days a week. Rivers don't conveniently stop flowing at the end of the human working day. Emergencies sometimes occur, such as sudden influxes of drainage water after heavy rainstorms coming off large areas of concrete like London Airport or the M25 motorway. One lock-keeper lost his life trying to remove a massive obstacle that was blocking his weir in the middle of the night.

In this situation the TWA thought it would be a good idea to try and maintain the SHWL by making the weirs operate automatically. The intention was not to put the lock-keepers out of a job but to eliminate the many short-term corrections they have to make to the weirs, sometimes while everyone else is safely asleep. At each lock and weir the lock-keeper would still be in charge of the automatic system, setting it to give the required water level and over-riding it manually if necessary.

After doing a feasibility study, which gave encouraging results, the TWA installed a pilot plant at Caversham Weir near Reading, Berkshire. This conrol system is now running and will be on trial for about a year. If it proves successful the Authority will go ahead and automate all the other weirs on the river in a similar way.

The basic principle is very straightforward — a closed-loop control system which raises or lowers the eight weir gates at Caversham according to the river level measured at the upstream side of the weir. A bank of ultrasonic level transducers, made by Sarasota Automation Ltd, measure this water level. Their electrical output signals are taken once every five seconds and then undergo arbitration, averaging and smoothing in the IBM PC to get a reliable value.

The lock-keeper inserts the required level of the river on a keyboard. In the computer this set value is compared with the actual level measured by the transducers and the differences between them is calculated. The result is a deviation, or error-signal in control engineering language. This deviation value is then processed by an algorithm which applies proportional plus integral terms to it, as in an industrial process controller. Integral action is introduced to nullify spurious deviations caused by river flow disturbances.

After this processing the level deviation value is used to operate another algorithm for selecting among the eight weir gates and determining by how much they are to be opened or closed. So out of the computer come eight binary signals for commanding the electrical gear which raises or lowers the motorised weir gates.

These gates are pivoted or radial types. They control the flow of water passing underneath them as they are raised or lowered by cables and winches driven by electric motors. In the Caversham scheme the three-phase drive motors are included in closed-loop position control servomechanisms, with transducers to measure the actual angular positions of the gates. So the command binary signals coming from the computer are in fact desired values of gate angle for setting these control loops. PE

READY-MADE P.C. BOARDS

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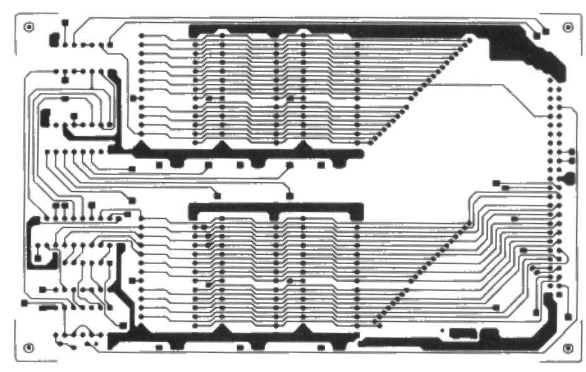

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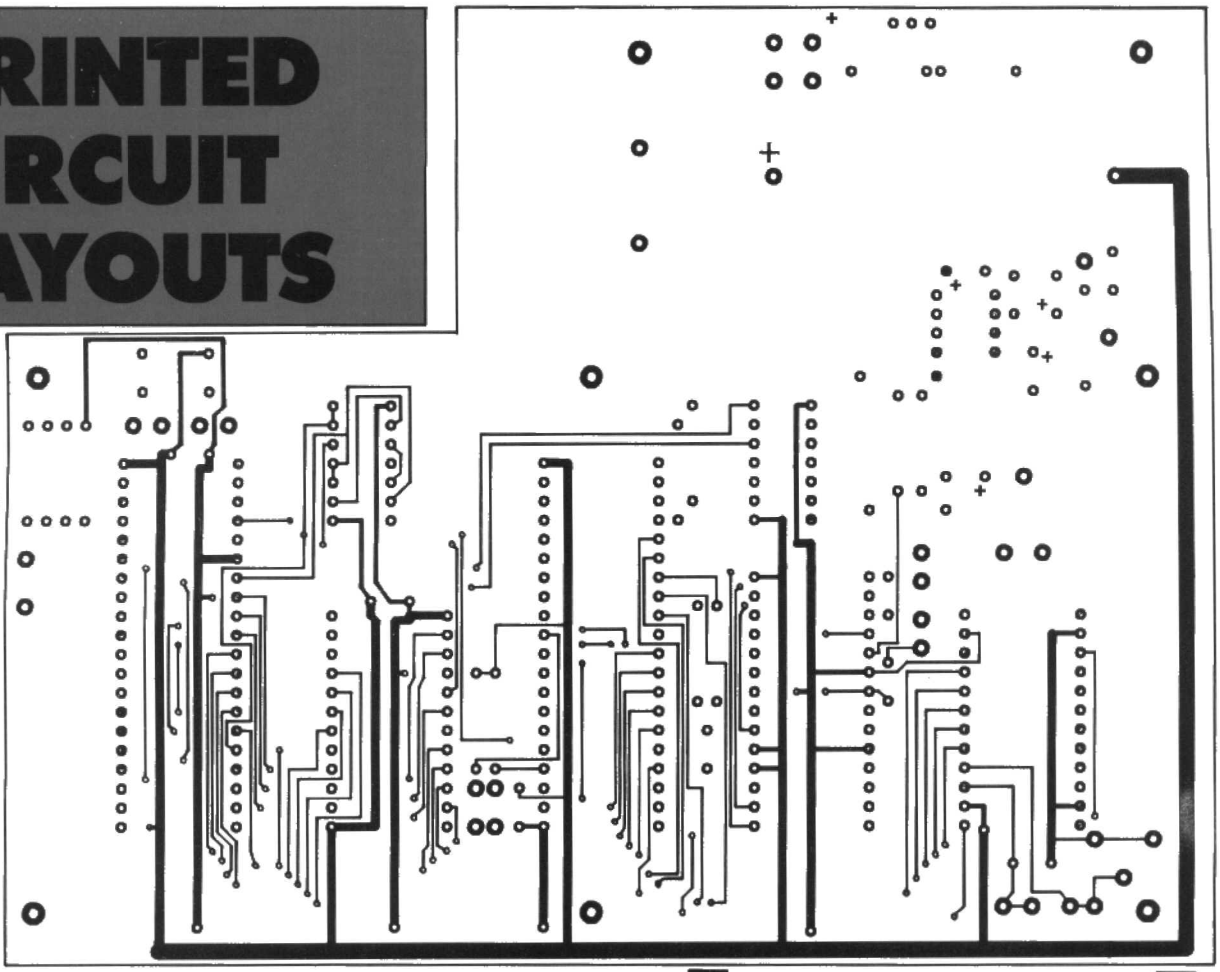
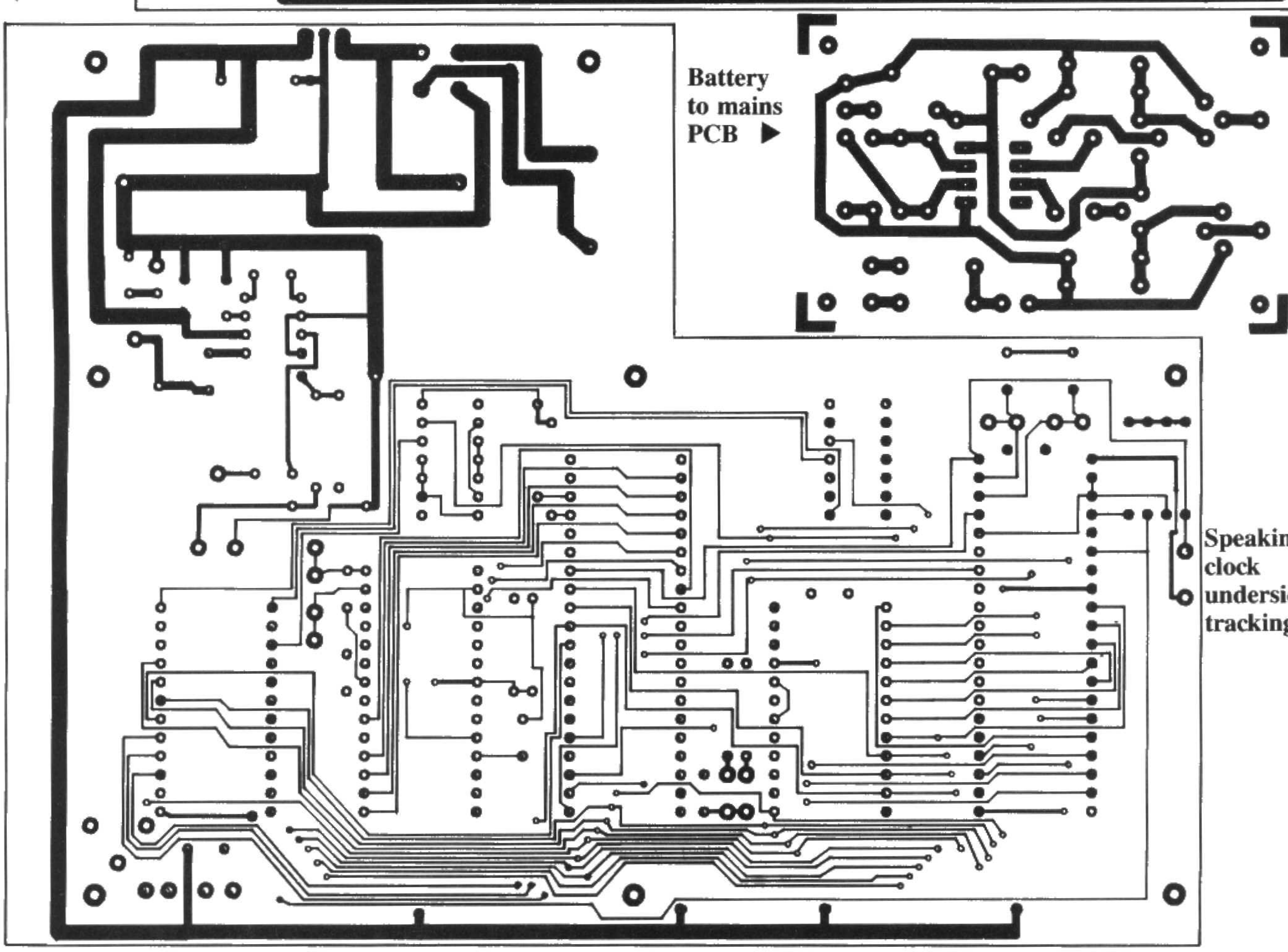


PE176 ▶
▼

Battery to mains PCB ▶



Speaking clock underside tracking